PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2004-289126
(43)Date of publication of application : 14.10.2004

(51)Int.Cl. H01L 21/027
G03F 7/20

(21)Application number : 2003-417259
(22)Date of filing : 11.11.2003

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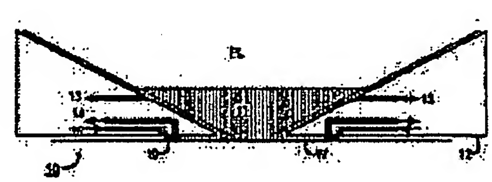
(30)Priority

Priority number :	Priority date :	Priority country :
2002 02257822	12.11.2002	EP
2003 03252955	13.05.2003	EP

(54) LITHOGRAPHY SYSTEM AND PROCESS FOR FABRICATING DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a lithography projector in which a space between a substrate and a projection system is filled with liquid while minimizing the quantity of the liquid required to be accelerated during a stage operation.
SOLUTION: In the lithography projector, the space between the final element of the projection system and the substrate table of the lithography projector is surrounded by a sealing member. A gas seal is formed between the sealing member and the plane of the substrate and the liquid is confined in that space.



CLAIMS

[Claim(s)]
[Claim 1]
- A radiation system which supplies a projection beam of radiation,
- The supporting structure which supports a patterning means to patternize a projection beam according to a pattern for which it asks,
- A board table holding a substrate,
- A projection system which projects a patternized beam on a target portion of a substrate,
- In a lithography projection apparatus which comprises the last element of this projection system, and a liquid distribution system which fills a space between these boards with a liquid selectively at least, it is this liquid distribution system,
- The last element of the above-mentioned projection system, and a seal member of the above-mentioned space between the above-mentioned board tables elongated along with a bordering portion at least,
- A lithography projection apparatus constituting by this seal member and a gas-seal means to form a gas seal between the surfaces of this board.
[Claim 2]
The equipment according to claim 1, wherein the above-mentioned gas-seal means is a gas bearing which supports the above-mentioned seal member on the above-mentioned substrate.
[Claim 3]
A gas inlet and the first gas derivation port which were formed in a field of the above-mentioned seal member where the above-mentioned gas-seal means countered the above-mentioned substrate, The equipment according to claim 1 or 2 being constituted by a means to supply gas to this feed port under application of pressure, and vacuum means which extracts gas from this first gas derivation port.
[Claim 4]
The equipment according to claim 3 having been arranged between the above-mentioned first gas derivation port connected with a gas source, and the above-mentioned gas inlet, and having further a feed port, **s.
[Claim 5]
The equipment according to claim 4, wherein the further above-mentioned feed port comprises a continuous annular slot in a field of the above-mentioned seal member facing the above-mentioned substrate.
[Claim 6]
The equipment according to claim 5, wherein a corner of the radiate innermost part of the above-mentioned slot has a radius.
[Claim 7]
Equipment given in any 1 clause of Claim 3, wherein the above-mentioned first gas derivation port comprises a continuous annular slot in a field of the above-mentioned seal member facing the above-mentioned substrate to 6.
[Claim 8]
The above-mentioned first gas derivation port and/or the above-mentioned gas inlet, Equipment

given in any 1 clause of Claim 3, wherein it comprises a means of the above-mentioned supply, each chamber between the above-mentioned vacuum means, and an opening of a feed port in the above-mentioned surface, or a derivation port and a chamber brings about flow restrictions lower than this opening to 7.

[Claim 9]

Equipment given in any 1 clause of Claim 3, wherein the above-mentioned gas inlet consists of a series of separate openings in a field of the above-mentioned seal member facing the above-mentioned substrate to 8.

[Claim 10]

Equipment given in any 1 clause of Claim 3 characterized by arranging a porous member in this gas inlet so that a flow of gas may be uniformly distributed to a field of a gas inlet to 9.

[Claim 11]

Equipment given in any 1 clause of Claim 3, wherein the above-mentioned gas-seal means is further provided with the second gas derivation port formed in the above-mentioned field of the above-mentioned seal member which countered the above-mentioned substrate and the above-mentioned first gas derivation port and this second gas derivation port are formed in both sides of the above-mentioned gas inlet to 10.

[Claim 12]

Equipment given in any 1 clause of Claim 3 having further a means to change a level of a portion of the above-mentioned field between the above-mentioned first gas derivation port and the above-mentioned gas inlet, to the remaining portion of the above-mentioned field to 11.

[Claim 13]

Equipment given in any 1 clause of Claim 3, wherein this equipment is further provided with a means to change a level of a portion of the above-mentioned field between edge of the above-mentioned first gas derivation port and a field nearest to the above-mentioned optic axis, to the remaining portion of the above-mentioned field to 12.

[Claim 14]

Equipment given in any 1 clause of Claim 3, wherein the above-mentioned gas-seal means is provided with a channel which is located in the neighborhood at an optic axis of a projection system, and is formed in the above-mentioned field rather than the above-mentioned first gas derivation port to 13.

[Claim 15]

The equipment according to claim 14, wherein the above-mentioned channel is the second gas inlet.

[Claim 16]

The equipment according to claim 15 currently opening the above-mentioned channel to environment on an oil level in the above-mentioned space.

[Claim 17]

Equipment given in any 1 clause of Claim 3, wherein the above-mentioned gas inlet is further arranged outside rather than the above-mentioned first gas derivation port from an optic axis of the above-mentioned projection system to 16.

[Claim 18]

Equipment given in any 1 clause of Claim 3, wherein an above-mentioned gas inlet and a gas derivation port comprise two or more lead pipes led to a slot in this side of this seal member that countered this board, respectively, and this slot that took an interval and has been arranged to 17.

[Claim 19]

Equipment given in any 1 clause of Claim 1 having further a sensor which measures distance between the above-mentioned field of the above-mentioned seal member, and topology of the above-mentioned substrate and/or the above-mentioned substrate to 18.

[Claim 20]

Equipment given in any 1 clause of Claim 1 having further an adjustment device which adjusts a pressure of gas in the above-mentioned gas-seal means in order to adjust rigidity between the above-mentioned seal member and the above-mentioned substrate, and/or distance between

the above-mentioned seal member and the above-mentioned substrate to 19.
[Claim 21]
So that a liquid may be drawn in a gap by capillary action, and so that it may prevent gas from/or a gas-seal component going into the above-mentioned space between the above-mentioned projection system and the above-mentioned substrate, Equipment given in any 1 clause of said claim, wherein a gap between the above-mentioned seal member and a field of this substrate that is inside the above-mentioned gas-seal means is small.
[Claim 22]
Equipment given in any 1 clause of said claim, wherein the above-mentioned seal member surrounds the above-mentioned space between the above-mentioned projection system and the above-mentioned substrate and forms a closed loop.
[Claim 23]
- A radiation system which supplies a projection beam of radiation,
- The supporting structure which supports a patterning means to patternize a projection beam according to a pattern for which it asks,
- A board table holding a substrate,
- A projection system which projects a patternized beam on a target portion of a substrate,
- In a lithography projection apparatus which comprises the last element of this projection system, and a liquid distribution system which fills a space between these boards with a liquid selectively at least, The minimum section field of this duct [in / this space is connecting with a liquid reservoir and a liquid through a duct, and / a field vertical to a flow direction of a fluid] is at least,

[Mathematical formula 1]

$$\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$$

A next door and **V are the quantity of a liquid which must be removed from this space in time t_{min}, A lithography projection apparatus which L is duct length, and eta is the viscosity of a liquid in this space, and is characterized by **P_{max} being a maximum allowable working pressure concerning this last element.
[Claim 24]
The equipment according to claim 23, wherein this space is sealed so that this liquid may not have the free upper surface when a liquid is in the above-mentioned space.
[Claim 25]
- A radiation system which supplies a projection beam of radiation,
- The supporting structure which supports a patterning means to patternize a projection beam according to a pattern for which it asks,
- A board table holding a substrate,
- A projection system which projects a patternized beam on a target portion of a substrate,
- In a lithography projection apparatus which comprises the last element of this projection system, and a liquid distribution system which fills a space between these boards with a liquid selectively at least, A lithography projection apparatus, wherein this liquid distribution system is provided with a restraint means which suppresses generating of a wave and includes a pressure release means in an uppermost surface of a liquid in this liquid distribution system further.
[Claim 26]
The equipment according to claim 25, wherein the above-mentioned restraint means consists of an existing flexible film.
[Claim 27]
The equipment according to claim 25 or 26 which the above-mentioned restraint means consists

of mesh, and is characterized by the maximal domain of the above-mentioned uppermost surface of the above-mentioned liquid being equal to an opening which is a mesh.

[Claim 28]

Claim 25 providing the above-mentioned restraint means with a safety valve, and passing a liquid with a specific pressure, equipment given in 26 or 27.

[Claim 29]

The equipment according to claim 25, wherein the above-mentioned restraint means are the above-mentioned liquid and a liquid of hyperviscosity which is nonmiscible.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
This invention,
- The radiation system which supplies the projection beam of radiation,
- The supporting structure which supports a patterning means to patternize a projection beam according to the pattern for which it asks,
- The board table holding a substrate,
- The projection system which projects the patternized beam on the target portion of a substrate,
- It is related with the lithography projection apparatus which comprises the last element of this projection system, and the liquid distribution system which fills the space between these boards with a liquid selectively at least.
[Background of the Invention]
[0002]
The term a "patterning means" [to use it in this Description] Becoming should be interpreted by the broad sense as what hits the means which can be used in order to give the patternizing section which is in agreement with the pattern which should be made by the target portion of a substrate to the entering radiation beam. The term "light valve" Becoming is also used in such a situation. Generally, the above-mentioned pattern is equivalent to the special stratum functionale made by the target portion in a device which are an integrated circuit and other devices (see the following). The following is contained in such a patterning means. namely
- Mask. The concept of a mask is a well-known thing in lithography, and not only various hybrid mask types but the mask type like a binary mask, a Levenson mask, and an attenuation phase shift mask is included in this. By arranging such a mask to a radiation beam, the alternative penetration (in the case of a penetrable mask) and alternative reflection (in the case of a reflexibility mask) according to the mask pattern of the radiation with which a mask is irradiated are enabled. When in the case of a mask the supporting structure is required for the position for which the entering radiation beam generally asks so that it is possible to hold a mask, it is a possible mask table of making it exercise to a beam.
- Programmable mirror array. As an example of such a device, the matrix address possible side which has a viscoelasticity control layer and a reflector is raised. Although the field where, as for the basal principle of such equipment, the address of the reflector (for example) was carried out reflects incident light as the diffracted light, the field by which an address is not carried out is reflecting incident light as the non-diffracted light. By using a suitable filter, it is possible to leave only the diffracted light and to carry out the filter of the above-mentioned non-diffracted light from a reflective beam. In this method, pattern formation of the beam is carried out according to the address pattern of a matrix address possible side. In embodiment of a programmable mirror array another again, the matrix arrayed of two or more small mirrors is used. Each of the mirror is separately leaned focusing on the axis by [which apply the local electric field for which it was suitable] depending especially or using a piezo-electric operating

means. If it says once again, a matrix address will be possible for a mirror and the mirror by which the address was carried out by that cause will reflect an incident radiation beam in the different direction from the mirror by which an address is not carried out. Thus, pattern formation of the reflected beam is carried out according to the address pattern of a matrix address possible mirror. Matrix addressing needed is performed using a suitable electronic means. In the situation of above-mentioned both, the patterning means can consist of one or more programmable mirror arrays. More information about the mirror array which referred to it here, the [for example, / United States patent] -- the [US No. 5,296,891 and / the] -- since it is indicated by PCT patent kind application the WO98/[US No. 5,523,193 and] 38597, and said WO98/33096, please refer to these contents for details. In the case of a programmable mirror array, the above-mentioned supporting structure is materialized, for example as a frame or a table, and if needed, this serves as a stationary type or serves as working.
- Programmable LCD array. the example of such composition -- the [United States patent] -- since it is indicated by US No. 5,229,872, for details, please refer to these contents. The supporting structure which can be set in this case as well as the above is materialized, for example as a frame or a table, and this also serves as a stationary type if needed, or it becomes working. Suppose that the remainder of the text is limited to the example which needs a mask and a mask table, and is explained in a specific part for the purpose of compaction. However, the general principle discussed in such an example should be understood in the more extensive situation of a patterning means which was already described.
[0003]
The lithography projection apparatus is usable in manufacture of an integrated circuit (IC). In this case, a patterning means generates the circuit pattern corresponding to each layer of IC. And image formation of this pattern can be carried out to the target portion (for example, one or the die beyond it is comprised) on the substrate (silicon wafer) with which the layer of the radiation sensitization raw material (resist) was applied. Generally, the single wafer contains the whole contiguity target partial network irradiated with one at a time one by one via a projection system. The present equipment using patterning with the mask on a mask table is classified into the machine of two different types. In one type of a lithography projection apparatus, each target portion is irradiated by exposing a whole mask pattern by one operation into a target portion. Such equipment is generally called the wafer stepper. In another equipment called step and scan equipment. Each target portion is irradiated by scanning a mask pattern gradually by a projection beam to a predetermined reference direction (the "scanning" direction), and scanning a board table to these direction and parallel, or anti-parallel simultaneously with this. Generally, since a projection device has the magnification coefficient M (generally <1), the speed V by which a board table is scanned becomes one M times the coefficient of the speed by which a mask table is scanned of this. if the further information about the lithography device which indicated here indicates by reference -- the [for example, / United States patent] -- it can obtain from US No. 6,046,792.
[0004]
In the manufacturing process which uses a lithography projection apparatus, image formation of the pattern (for example, it can set on a mask) is carried out on the substrate selectively covered in the layer of radiation sensitization material (resist) at least. A substrate passes through various kinds of processes like priming, a resist application, and soft bake in advance of this image formation step. A substrate passes along other processes like measurement/inspection of postbake (PEB), development, postbake, and an image formation future after exposure. The arrangement of this process is used as a standard for patternizing each layer of the element like IC, for example. such a layer by which pattern formation was carried out -- and it passes through various processes of etching, an ion implantation (doping), metallization, oxidation, chemical machinery polish, etc. which are the purposes of finishing each layer altogether. When the layer of several sheets is needed, it is necessary to repeat a whole process or its modification in each new layer. Eventually, the array of an element is formed on a substrate (wafer). Next, these elements are separated from mutual by the technique like dicing or sewing. And a carrier is equipped with each element or it may be connected to a pin. . The

further information about such a process was published from the McGraw-Hill publishing company in 1997. Peter van Zant work, "microchip manufacture : The 3rd edition of the books ("Microchip Fabrication:A Pratical Guide to Semiconductor Processing") of the name practical use guide" to a semiconductor process, Since it is indicated to ISBN0-07-067250-4, please refer to these contents for details.
[0005]
For the purpose of compaction, a projection system shall be called a "lens" from this. However, this term should be interpreted by the broad sense as what covers the projection system various type which contains a dioptrics system, a reflected-light study system, and a catadioptric-system system, for example. A radiation system can be provided also with the component which works again according to such a design type of either which performs derivation of the projection beam of radiation, shaping, or control. Such a component is also called a "lens" intensively or in independent henceforth. A lithography device is a thing of a type which has two or a board table beyond it (and or two or the mask table beyond it). It is used by the additional table in such a "multistage" device, standing in a row. Or while other one or more tables are used for exposure, a preliminary process is performed on one or more tables. by reference — a dual stage lithography device — the [United States patent] — the description is made in US No. 5,969,441 and international patent application the WO98 / No. 40791.
[0006]
Dipping the substrate in a lithography projection apparatus in the liquid like water which has a comparatively high refractive index is proposed so that the space between the last element of a projection system and a substrate may be filled. Since exposure radiation has shorter wavelength in a liquid, the point in this is making image formation of a smaller feature possible. (It is thought that effective NA in a system also increases by the effect of a liquid.)
[0007]
However, dipping a board table in a liquid means that there are a lot of liquids which must be accelerated during scanning exposure. this -- an addition -- or a turbulent flow [in / a more powerful motor is needed and / a liquid] — ** -- the influence which ****** and cannot predict whether it is better is brought about.
[0008]
A lithography projection apparatus has some difficulties about having a liquid. For example, making a liquid flow out produces a problem by destroying the vacuum, when [in which it interferes with an interferometer] it is necessary to depend especially and and a beam needs to be maintained at a vacuum in a lithography projection apparatus. A liquid is used at a remarkable rate as suitable preventive measures are not taken by it.
[0009]
The difficulty in keeping the depth of a liquid constant on the further problem relevant to dipping lithography and the difficulty in conveyance of the substrate to the bottom of an image formation position, i.e., the last projection system element, and conveyance from the image formation position are included. Contamination (based on the chemical which dissolved in the liquid) of a liquid, and the rise of the temperature of a liquid have influence harmful to the image formation quality which can be attained.
[0010]
It is necessary to perform the process for protecting especially the optical element of a projection system in the case of the control loss of failure of a computer, a power failure, or equipment by a certain Reason. It is necessary to establish the process of preventing a liquid from falling in other components of equipment.
[0011]
When a liquid has a free face and a liquid distribution system is used, it is necessary to perform a process for the power applied to a liquid distribution system to prevent a wave from occurring in the free face. The wave can tell vibration to a projection system from a substrate of operation.
[0012]
In the international patent application number WO 99/No. 49504, the lithography device with which a liquid is supplied to the space between a projection lens and a wafer is indicated. When a

wafer is scanned in the direction of X under a lens, a liquid is supplied on +X side of a lens and is taken up on -X side.
[Description of the Invention]
[Problem to be solved by the invention]
[0013]
This invention makes the minimum quantity of the liquid which needs to be accelerated between stage operations, and an object of this invention is to provide the lithography projection apparatus which filled the space between a substrate and a projection system with the liquid.
[Means for solving problem]
[0014]
In a lithography projection apparatus which was specified in the paragraph of the beginning, this purpose and other purposes are attained according to this invention. Here, it is the above-mentioned liquid distribution system,
- The last element of the above-mentioned projection system, and the seal member of the above-mentioned space between the above-mentioned board tables elongated along with the bordering portion at least,
- It comprises this seal member and a gas-seal means to form a gas seal between the surfaces of this board.
[0015]
From carrying out a gas-seal means in this way, and forming a non-contact seal between a seal member and a substrate, even if it is a time of the substrate operating under a projection system during scanning exposure, a liquid is confined in a space between the last element of a projection system, and a substrate, for example.
[0016]
A seal member makes one closed loop form of circular, a rectangle, or other form surrounding a space, or U type form or form of a space which has not only closed having elongated along with a side on the other hand is also possible for it, for example. When a seal member has not closed and a substrate is scanned under a projection system, a seal member is arranged so that a liquid may be shut up.
[0017]
Preferably, a gas-seal means is a gas bearing which supports this seal member. This has the strong point in which identical parts of a liquid distribution system are usable to both ceilings of a liquid in a space between a bearing and the last element of a projection system, and a substrate, and this reduces complexity and weight of a seal member. Experience before obtaining from use of a gas bearing in vacuum environment can be employed efficiently.
[0018]
Preferably, a gas-seal means is constituted by the gas inlet and the first gas derivation port which were formed in the field of this seal member that countered the above-mentioned substrate, a means to supply gas to this feed port under application of pressure, and the vacuum means which extracts gas from this first gas derivation port. A gas inlet is further arranged outside rather than this first gas derivation port from the optic axis of the above-mentioned projection system still more desirably. Thus, the flow of the gas in a gas seal confines a liquid most effectively toward the inside. In this case, a gas-seal means is further provided with the second gas derivation port advantageously formed in the field of the seal member which countered the substrate, and the first gas derivation port and the second gas derivation port are formed in the both sides of a gas inlet. The second gas derivation port makes it possible to stop the gas which slips out from a gas inlet by the environment surrounding a seal member to the minimum. Therefore, the risk of the gas of interfering with an interferometer or reducing the vacuum in a lithography device which falls out and comes out is stopped to the minimum.
[0019]
The liquid distribution system is provided also with the sensor which measures the distance between the topology of the field of a seal member, and the uppermost surface of a substrate and/or a substrate. Thus, an adjustment device may be used in order to change the field of a seal member, and the distance between substrates by adjusting a gas-seal means with a

feedforward method or a feedback method, for example.
[0020]
This equipment is further provided with a means to change a level of a portion of this field of this seal member to the remaining portion of a field with the first gas derivation port and edge of a field nearest to an optic axis. This is that adjustment of a pressure which confines a liquid in a space is made apart from adjustment of a pressure under a feed port, and it can adjust height of a seal member on a substrate, without disturbing balance of power which holds a liquid in a space. This is made possible and an option is using a means for changing a level of a portion of a field between the first gas derivation port or the second gas derivation port, and a gas inlet to the remaining portion of a field. These three systems are usable in any combination.
[0021]
Moreover it divides a ceiling function and a bearing function of a gas-seal means, an option is establishing a channel which is located near the optic axis of a projection system and formed in a field of a seal member rather than the first gas derivation port. While a pressure of this channel can be changed so that a liquid may be confined in a space, It will be only small, even if it acts only in order that these may support a seal member and there is a ceiling function, since it is usable in order that a gas inlet and a gas derivation port may change height of a seal member on a substrate.
[0022]
A still more advantageous future is a porous member arranged in a gas inlet in order to distribute the flow of gas to the field of a gas inlet uniformly.
[0023]
This is convenient although a gas inlet and a gas derivation port are formed, and each of a gas inlet comprises two or more lead pipes led to the slot in this side of this seal member that countered this board, and this slot that took the interval and has been arranged.
[0024]
The small thing of the gap between this seal member and the field of this board that exists inside this gas-seal means is desirable so that a liquid may be drawn in a gap by capillary action, and so that the gas from/or a gas-seal component may be prevented from going into this space. The seal divided and stabilized by balance between the capillary action which draws a liquid, and the flow of the gas which extrudes it is formed under a seal member.
[0025]
The space between a substrate and a projection system is filled with a liquid, and it sets it as the further purpose to provide the lithography projection apparatus which presses down the propagation of the disturbance between a substrate and a projection system to the minimum.
[0026]
In a lithography device which was specified in the paragraph of the beginning, this purpose and other purposes are attained according to this invention. Here, the minimum section field of this duct [in / this space is connecting with the liquid reservoir and the liquid through the duct, and / a field vertical to the flow direction of a fluid] is at least,
[Mathematical formula 1]

$$\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$$

A next door and **V are the quantity of the liquid which must be removed from this space in time t_{min}, L is duct length, and eta is the viscosity of the liquid in this space, and **P_{max} is a maximum allowable working pressure concerning this last element.
[0027]
As for this equipment, a liquid has the strong point in which it can be controlled thoroughly so that it may not have a big free face which a wave generates. That is, the ene closing of a space

or the reservoir is carried out at the topmost part, and the reservoir is filled with the liquid. This through a duct within predetermined time (time of the crash measured experimentally) the quantity of the fluid which can flow out, It is because a liquid can slip out through a duct before the pressure in a space reaches the level made to generate damage, since it is so large enough that the damage to the last element of a projection system may be avoided in the case of crash of equipment. When the seal member operates to the last element, it must slip out of a liquid. Otherwise, the hydrostatic pressure poured on the last element between the relative movements of the last element to a seal member will do damage to the last element.

[0028]

In another mode of this invention, a lithography device which was specified in the paragraph of the beginning is provided. Here, further, in the uppermost surface of the liquid in this liquid distribution system, a liquid distribution system suppresses generating of a wave, and is provided with a restraint means including a pressure release means.

[0029]

Thus, generating of a wave is suppressed when a restraint means contacts the uppermost surface of a liquid. However, since the damage to the last element is avoided in the case of crash, moreover, it can slip out of a liquid from this space.

[0030]

One method of providing a restraint means is putting the liquid in a space, and the liquid of nonmiscible hyperviscosity on the liquid uppermost surface in a space through the existing flexible film. In these each case, a pressure release function is brought about with the flexibility of a restraint means.

[0031]

In another mode of this invention,

- The step which provides the substrate selectively covered with the layer of the radiation sensitive material at least,
- The step which supplies the projection beam of radiation using a radiation system,
- The step which gives a pattern to the section of a projection beam using a patterning means,
- The step which projects the beam with which radiation was patternized by the target portion of the layer of a radiation sensitive material,
- The device manufacturing method which consists of a step which supplies a liquid so that the space between the last elements of a substrate and the projection system used in the above-mentioned projection step may be filled is provided,
- or [forming a gas seal between the seal member of this space elongated along with the bordering portion at least, and the surface of this substrate] -- or
- It is either of whether the liquid reservoir connected with this space with a liquid through a duct is provided,
- This duct,

[Mathematical formula 2]

$$\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$$

Have the minimum section field in a field vertical to the flow direction of ******, and here, **V is the quantity of the liquid which must be removed from this space in time t_{min}, L is duct length, eta is the viscosity of the liquid in this space, and it is characterized by **P_{max} being a maximum allowable working pressure on this last element -- or

- Control generating of the wave of this liquid by a restraint means, and make the pressure of this liquid cancel.

[0032]

Although detailed reference explanation is given in manufacture of IC about the directions of the

equipment by this invention in the text, it should be understood clearly that such equipment is usable also in many other uses. For example, the equipment by this invention may be used for manufacture of the guidances for integrated optics equipment and magnetic domain memories and detecting patterns, liquid crystal display panels, thin film magnetic heads, etc. In such an alternative use, it is clear for the specialist in the technical field concerned that the term's of the "reticle", the "wafer", and the "die" which were used in the text it may be used, transposing to a more general term [say / a "mask", a "substrate", and a "target portion"], respectively.

[0033]

The term of the "radiation" and the "beam" which were used in this Description, All types including not only the particle beam like an ion beam or an electron beam but ultraviolet rays (for example, it has the wavelength of 365 nm, 248 nm, 193 nm, 157 nm, or 126 nm) of electromagnetic radiation is covered.

[0034]

Attached Drawings shall be carried out for the detailed explanation about the embodiment of this invention to reference only in the method of illustration. The same reference number shall be similarly included in parts through a complete diagram.

[Work example 1]

[0035]

Drawing 1 shows the lithography projection apparatus based on the original embodiment of this invention. Radiation system Ex and IL which supply the projection beam PB (for example, DUV radiation) of radiation provided also with radiation source LA in this embodiment with this special equipment, First object table (mask table) MT which connected with the first positioning means holding mask MA (for example, REKUCHIRU) that mask-holder w Has and positions a mask correctly to item PL, Second object table (board table) WT which connected with the second positioning means that is provided with the substrate holder holding the substrate W (for example, resist application silicon wafer), and positions a substrate correctly to item PL, It is constituted by projection system ("lens") PL (for example, reflective refraction lens system) which carries out image formation of the irradiation portions of mask MA to the target portion C of the substrate W (for example, one or the die beyond it is comprised). This equipment is a penetration type (that is, it has a transmission mask) as shown here. However, generally the reflective type thing which has a reflecting mask, for example is also possible. Or the patterning means of other kinds like the programmable mirror array which is a type relevant to the above of this equipment is also usable.

[0036]

Source LA (for example, excimer laser) makes the beam of radiation. After this beam crosses the conditioning means like the beam expander Ex directly or, for example, it is supplied to lighting system (lighting system) IL. Lighting-system IL comprises adjustment device AM which sets up the exterior of intensity distribution and/, or the internal radiation range (it is generally equivalent to sigma-outer and sigma-inner, respectively) in a beam. Lighting-system IL is generally provided with other various components like the integrator IN and capacitor CO. Thus, the beam PB with which mask MA is irradiated has the homogeneity and intensity distribution for which it continues and asks in the section.

[0037]

being related with drawing 1 -- source LA -- the inside of the housing of a lithography device -- it is (this is large when a source is a mercury lamp) -- however, it comments also on it being possible to separate from a lithography projection apparatus and to arrange. In this case, the radiation beam which source LA makes is drawn in equipment (guide mirror for which it was suitable). In the scenario of this latter, source LA is an excimer laser in many cases. This invention and a claim cover both scenario of these.

[0038]

Then, the beam PB enters into mask MA currently held on mask table MT. The beam PB passes lens PL which crosses mask MA and doubles the focus of the beam PB on the target portion C of the substrate W. By the second positioning means (and interference measurement means IF), board table WT can exercise correctly, in order to double a position with the different target

portion C in the course of the beam PB, for example. Similarly, it is usable after the first positioning means searches mask MA mechanically, for example from a mask library, or so that mask MA may be correctly positioned to the course of the beam PB between scanning motion. Generally, movement of object table MT and object table WT is performed by a long-stroke module (coarse adjustment positioning) and the short stroke module (slight movement positioning). About this, it is not showing clearly to drawing 1. however, in the case of a wafer stepper (step and scan equipment — by contrast), mask table MT is only connected with a short stroke actuator, or is fixed.
[0039]
The equipment which expressed here is usable in two different modes.
- In step mode, mask table MT is kept fundamental to the state of rest. And the whole image of a mask is projected on the target portion C by one operation (namely, 1 time of "flash plate"). Next, board table WT is shifted to a x direction and/, or a y direction, and the different target portion C may be irradiated by the beam PB.
- In scanning mode, although the same scenario is applied fundamentally, the predetermined target portion C is not exposed with 1 time of a "flash plate" here. Instead, mask table MT can exercise for a prescribed direction (what is called a "scanning direction", for example, a y direction) at the speed v, and the beam PB scans the image of a mask by it. It can come, simultaneously board table WT exercises for a uniform direction or a counter direction by speed V=Mv. Here, M is the magnification (generally M= 1/4 or 1/5) of lens PL. Thus, it becomes possible to expose the comparatively big target portion C, without reaching a compromise in resolution.
[0040]
Drawing 2 shows a projection system and the liquid reservoir 10 between substrate stages. The liquid 11 which has a comparatively high refractive index which is water is filled via introduction/derivation duct 13 by the liquid reservoir 10. There is an effect of a liquid in having shorter wavelength with a liquid and enabling resolving of a smaller feature rather than the radiation of a projection beam can set to air or a vacuum. The wavelength of a projection beam and the numerical aperture of a system especially determine the resolution limit of a projection system. It is thought that existence of a liquid also increases the number of effective apertures. The liquid is effective for increasing depth of field with a fixed numerical aperture.
[0041]
The reservoir 10 forms the non-contact seal to a substrate in the surroundings of the image field of a projection system.
The liquid is shut up so that the space between a substrate face and the last element of a projection system may be filled.
The reservoir is formed from the seal member 12 which surrounded this and has been arranged under the last element of projection system PL. It is put into a liquid to the space in the seal member 12 under a projection system. The seal member 12 is elongated now exceeding a little last element of a projection system, an oil level goes up to the last element, and the buffer of a liquid is brought about. The seal member 12 is an upper bed part, and has the inner circumference which is preferably in agreement with the step or its last element of a projection system just.
And it may be round, for example.
In a pars basilaris ossis occipitalis, although inner circumference is not necessarily restricted to this, it is in agreement with the form of a rectangular image field just.
[0042]
A liquid is shut up by the reservoir with the pars basilaris ossis occipitalis of the seal member 12, and the gas seal 16 between the substrate W surfaces. a gas seal -- the gas like air or a synthetic air — however, it is preferably formed by N_2 or other inactive gas. Such gas is supplied to the gap between the seal member 12 and a substrate under application of pressure via the feed port 15, and is extracted by the first derivation port 14. The overpressure to the gas inlet 15, the vacuum level of the first derivation port 14, and the geometry of a gap are adjusted so

that the high-speed airstream to the inside which shuts up a liquid may arise. This is shown more in details in drawing 3.

[0043]

A gas seal is formed from the two annular slots 18 and 19, and these annular slots are connected with the first feed port 15 and the first derivation port 14 by the small conduct (conduct) which took a space and followed the surroundings of a slot, respectively. The feed port 15 and the derivation port 14 are slots or slits which are two or more separate orifices surrounding a periphery of the seal member 24, or continued. An annular big hollow to a seal member is provided in a feed port and the derivation ports of each, and forms a manifold. By acting as a gas bearing, a gas seal is effective also in supporting the seal member 12.

[0044]

The small and longer one of the gap G1 on the outside of the gas inlet 15 is preferred so that resistance may be given to a flow of air which goes outside, but it does not necessarily need to be so. The gap G2 of a semicircle upper bed of the feed port 15 formed of many surrounding small holes of a seal member is somewhat large, and certainly distributes surrounding gas of a seal member fully. Gap G3 is chosen so that a flow of gas which passes along a seal may be controlled. In vacuous distribution, the gap G4 has become greatly so that may be made well. The derivation port 14 is formed of many small holes by the same method as the feed port 15. The gap G5 is small so that it may avoid a lot of liquids entering and barring a vacuum, and so that [so that it may prevent spreading gas/oxygen into a liquid in a space, and] this may always be certainly filled with a liquid by capillarity.

[0045]

Thus, a gas seal is the balance between the capillary force which draws a liquid in a gap, and the airstream which extrudes a liquid. When capillary force will be reduced if a gap becomes large from G5 G4, and the flow of air increases, the boundary line of a liquid serves as this field, and it is stabilized even when a substrate runs by the bottom of projection system PL.

[0046]

The flow of the gas by which the pressure differential between not only the size and geometry of gap G3 but the feed port in G2 and the derivation port in G4 passes along the seal 16 is determined, and this pressure differential is determined according to a concrete embodiment. On the other hand, the length of gap G3 is short, and a remarkable effect can be attained when the absolute pressure in G2 is twice the absolute pressure in G4. In this case, gas velocity is the sound velocity in gas, and does not increase any more. Therefore, the flow of stable gas is attained.

[0047]

By reducing gas introducing pressure and making a liquid go into the gap G4, by sucking out with a vacuum system, a gas derivation system may be used, also when removing a liquid thoroughly from a system. This can be easily adjusted, as well as the gas used in order to form a seal in order to deal with a liquid. The pressure regulation of a gas seal is used also in order to make the liquid which passes along the gap G5 flow certainly so that the liquid of the gap G5 heated by friction may not disturb the liquid temperature of the space under a projection system, when the substrate operates.

[0048]

The form of the surrounding seal member of a gas inlet and a derivation port should be chosen so that laminar flow may be brought about as much as possible, in order to reduce a turbulent flow and vibration. The flow of gas should be adjusted so that change of the flow direction in the interface of a liquid may become as large as possible, in order to bring about the maximum force which shuts up a liquid.

[0049]

A liquid distribution system circulates the liquid of the reservoir 10, and, thereby, supplies a fresh liquid to the reservoir 10.

[0050]

The gas seal 16 can make the power of sufficient size to support the seal member 12. In order to actually raise the effective kilogram supported by the seal member 12, it is necessary to carry

out bias of the seal member 12 to a substrate direction. In any case, in a static position, the seal member 12 is substantially held in XY side (vertical to an optic axis) as opposed to a projection system under this, but it is separated from a projection system. The seal member 12 moves to a Z direction, and Rx and Ry freely.
[Work example 2]
[0051]
The 2nd embodiment is shown in drawing 4 and drawing 5. The 2nd embodiment is the same as the 1st embodiment except for the contents of the description below.
[0052]
In this embodiment, the second gas derivation port 216 is established in the opposite side of the gas inlet 15 to the first gas derivation port 14. In this method, the gas which falls out from the gas inlet 15 outside, and appears from the optic axis of equipment in it is sucked up by the second derivation port 216 connected with the vacuum source. Thus, gas is prevented from slipping out from a gas seal so that the vacuum in which interferometer reading or the projection system, and/or the substrate are accommodated for gas, for example, and interference may be impossible.
[0053]
Other advantages of this example which uses two gas derivation ports are that this design is dramatically similar with the design of the air bearing before used in the lithography device. Therefore, it is possible to apply directly experience obtained from such an air bearing to the gas seal of this example. Since especially the gas seal of the 2nd embodiment is suitable for the use as a gas bearing not only as a seal means, it can use this for support of the weight of the seal member 12.
[0054]
In order to measure the bottom of the seal member 12, and the distance between the substrates W, or in order to measure the topology of the upper surface of the substrate W, a sensor is formed effectively. In order to change the pressure impressed to 14, 15, and 216 of a gas inlet and a derivation port, it is possible to use an adjustment device, and the pressure P2 which shuts up the liquid 11, and the pressures P1 and P3 which support the seal member 12 are changed into a reservoir. Therefore, the distance D between the seal member 12 and the substrate W is changed, or it is maintained by fixed distance. It may be used for the same adjustment device maintaining the field of the seal member 12. The same adjustment device may be adjusted by either a feedforward adjustment loop or the feedback adjustment loop.
[0055]
Drawing 5 shows in detail how a gas seal is adjusted and it gets, in order to adjust independently to a reservoir the pressure P2 holding a liquid, and the pressure P3 which supports the seal member 12. Since this special adjustment provides the method of pressing down the liquid loss under operation to the minimum, it is useful. In the 2nd embodiment, regulation of the pressures P2 and P3 is enabled independently, and the condition under exposure is changed. It is set to the level which differs in the liquid loss for every unit time that condition changes, a different scan speed or when the edge of the substrate W probably overlaps by the seal member 12. This is attained by providing a means to change the distance over the substrate W of each portion in the field of the seal member 12 facing the substrate W. The portion 230 between the first gas derivation port 14, the portion 220 between the edge of the seal member 12 nearest to an optic axis and the gas inlet 15, and the first gas derivation port 14 and the portion 240 between the second gas derivation port 216 and the gas inlet 15 are included in such a portion. An electrostrictive actuator is used for these portions, for example, and they operate in the direction of substrate W, and the direction which separates from the substrate W. That is, the bottom of the seal member 12 comprises an electrostrictive actuator (desirably stack). This electrostrictive actuator can be extended/contracted by giving the potential difference which crosses these. It is also possible to use other mechanical means.
[0056]
The pressure P3 made under the gas inlet 15, the pressure P5 of gas impressed to the gas inlet 15, the first gas derivation port 14, and the second gas derivation port 216 -- it is alike,

respectively and is determined by the distance D between the pressures P6 and P4 of gas impressed, and the bottom of the seal member 12 which faced the substrate W and the substrate W. Horizontal distance between a gas inlet and a gas derivation port also affects it.
[0057]
Weight of the seal member 12 is amended by the pressure P3, and, thereby, the seal member 12 decides the distance D from the wafer W. Reduction in D serves as an increase in P3, and an increase in D serves as reduction of P3. Therefore, this can be called self-regulating system.
[0058]
Only adjustment of the distance D is enabled by the pressure P4, P5, and P6 in fixed pushing force by the pressure P3. However, P5, P6, and combination of D make the pressure P2 which is a pressure which holds the liquid 11 to a reservoir. Quantity of a liquid which slips out of a container of a liquid with a predetermined pressure level is computable, and a pressure in liquid P_{LIQ} is also important for it. When P_{LIQ} is larger than P2, a liquid escapes from a reservoir and it comes out of it. moreover -- case P_{LIQ} is smaller than P2 -- good -- better or it is generated by ****** air bubbles into a liquid. It is desirable to maintain P2 to a value slightly smaller than P_{LIQ} so that air bubbles may not be made certainly, and so that so many liquids may fall out and it may not appear in a liquid, when this liquid needs to be exchanged. Preferably, this is all made by the constant D. Since quantity of a liquid which falls out and comes out will change by a square of the distance D1 if the distance D1 between the portion 220 and the wafer W is changed, quantity of a liquid which slips out of a reservoir is considerably changeable. Change of distance needed is about only 1-mm thing, and is 10 micrometers desirably. This is easily made possible by piezo-electric stack which has the operation voltage of order beyond 100V.
[0059]
Or it is possible by arranging a piezoelectric device at the pars basilaris ossis occipitalis of the portion 230 to adjust liquid quantity of which it can slip out. It is effective in changing the pressure P2 to change the distance D2. However, probably, this solution needs adjustment of the pressure P5 in the gas inlet 15, in order to maintain the constant D.
[0060]
Naturally, it is also possible for low [of the portion 240] to change the distance D3 between a portion and the substrate W in a similar way, and it is also possible to use it for each adjustment of P2 and P3. It will be understood that it is possible to combine and to adjust separately all of the pressure P4, P5 and P6, the distance D1 and D2, and D3 in order to change P2 and P3 into a desired value.
[0061]
The 2nd embodiment is actually effective in especially use in active management of liquid quantity of the reservoir 10. A standby state of a projection device with which image formation of the substrate W is not performed will be in a state where a gas seal is active, in order that it may support the seal member 12 by that cause, although a liquid of the reservoir 10 is empty. After the substrate W has been arranged, a liquid is introduced in the reservoir 10. Next, image formation of the substrate W is carried out. Before removing the substrate W, a liquid from a reservoir can be removed. A liquid in the reservoir 10 is removed after exposure of a last substrate. A gas purge must be applied so that a field where a liquid was before filled whenever it removed a liquid may be dried. In equipment, a liquid can be easily removed thoroughly according to the 2nd embodiment by changing P2, maintaining the constant P3, as mentioned above. In other embodiments, when changing P5 and P6 (in and the in the suitable case when required also in case of P4), same effect can be attained.
[Work example 3]
[0062]
As shown in drawing 6, the channel 320 is formed in a field of the seal member 12 which faced the substrate W inside the first gas derivation port 14 (still closer to an optic axis of a projection system) as an alternative of the 2nd embodiment, or the further deployment. The channel 320 has the same composition as 14, 15, and 216 of a gas inlet and a derivation port.
[0063]

It is possible to change the pressure P2 independently [the pressure P3] by using the channel 320. Or liquid consumption from a reservoir under operation is considerably reduced by carrying out the opening of the channel from an oil level of the reservoir 10 to upper ambient pressure. Although the channel 320 can be combined also with an embodiment like other throats and it might be used especially combining the 1st embodiment, this example was described in combination with the 2nd embodiment. The further strong point is that the gas inlet 15 and the first gas derivation port 14 (it is [in / again / a certain specific embodiment] also the second gas derivation port 216) are not disturbed.

[0064]

Although three elements are shown here, it is possible to take in even how many channels to the field of the seal member 12 facing the substrate W. Each channel is given the pressure in order to improve the rigidity of a liquid distribution system, liquid consumption, stability, or other characteristics.

[Work example 4]

[0065]

The 4th embodiment shown in drawing 7 and drawing 8 is the same as the 1st embodiment except for the contents given in the following. However, the 4th embodiment can also be effectively used here with the embodiment besides either of a description.

[0066]

In the 4th embodiment, the porous members 410, such as porous carbon and a porosity ceramic member, are preferably attached to the gas inlet 15. Here, gas escapes from the bottom of a seal member and it comes out of it. Preferably, the bottom of a porous member is on the same flat surface as the bottom of a seal member. The gas which is unrelated to the field which is not completely (in this case, it can set to the substrate W) even as for this porous carbon component 410, escapes from the feed port 14, and comes out is well distributed to the whole exit of a feed port. When the field where a gas seal contacts in this point when the seal member 12 is selectively arranged on the edge of the substrate W is not even, the strong point acquired by using the porous member 410 is also clear.

[0067]

In another form of the 4th embodiment, it is possible to arrange the porous member 410 to the vacuum channel 14. The porous member 410 should have the hole chosen so that a pressurization state might be maintained, avoiding ****** or ****** pressure loss. This is advantageous when carrying out image formation of the edge of the substrate W, and the gas bearing operates an edge top of the substrate W. Even if precompression in an edge position loses, it will be because change of precompression is reduced considerably and a vacuum channel is not polluted by gas of a large quantity and a variety in a continuous change of flying height on a stage, and power.

[Work example 5]

[0068]

It has a liquid in the reservoir 10 generally exposed to gas which has a free surface, and which is called air in all the above-mentioned embodiments. this -- the last element of projection system PL -- a projection system -- still water -- it comes out in order to prevent destroying in crash by power increasing. During crash, when projection system PL acts to it, a liquid in the reservoir 10 is not made to control, but it is obliged for a liquid to go up up easily. a surface wave produces a fault of this solution during operation in a free surface -- thereby -- projection system PL from the substrate W -- good -- better or it is telling ****** disturbance.

[0069]

The one method of solving this problem is that the reservoir 10 is made to be contained thoroughly [especially that upper surface] in a seal member. A liquid is supplied to the reservoir 10 through a duct from the second reservoir. in a projection system since it is obliged for this second reservoir to be able to have an uppermost surface which is not controlled, and for a liquid to go in the second reservoir through a duct during crash -- the big still water to the first reservoir 10 -- it avoids that power arises.

[0070]

In such a closed system, the local increase in the pressure of the liquid in a projection system is avoided by certainly having a section field where the duct connected with a reservoir is equal to the duct which has a radius according to the following equation.
[Mathematical formula 3]

$$R = \left(\frac{8\Delta V\eta L}{\pi\Delta Pt}\right)^{1/4}$$

R is a duct radius, **V is the quantity of the liquid which must be removed from the reservoir 10 within the time t here, L is the length of a duct, and eta is the viscosity of a liquid, and **P is a pressure differential between the second reservoir and the first reservoir 10. A board table may crash at 0.2 m (it measures by experiment)/second in speed. And when assumption that $**P_{max}$ is 10^4Pa (it can last before a damage produces the last element of a projection system in a maximum pressure) is built, a required pipe radius is about 2.5 mm to the duct length of 0.2 m. Desirably, the effective radius of a duct is twice [at least] the minimum obtained from a formula.
[0071]
While projection system PL is moreover protected at the time of crash, formation of a wave is avoided in a liquid of the reservoir 10, and an option is providing a free surface of a liquid with the inhibiting film 510 in an uppermost surface of a liquid of the reservoir 10. This solution needs the safety means 515 in order to make a liquid discharge without making it too high a pressure in crash. The one solution is shown in drawing 9. When an inhibiting film comprises a flexible material, and a liquid makes this transform the existing flexible inhibiting film 510 before a pressure of a liquid reaches predetermined allowable maximum, A liquid is attached with a wall or a projection system of the seal member 12 by a method of slipping out between projection system PL and the inhibiting film 510 or of between an inhibiting film and a seal member, respectively. Thus, a liquid is able to slip out of a safe film, without doing damage at projection system PL in crash. A thing of the reservoir 10 for which it has a space on an inhibiting film of volume at least about this embodiment is clearly desirable. Therefore, although it is so hard enough that formation of a wave can be avoided in an uppermost surface of a liquid in the reservoir 10, an existing flexible film is not hard to a forge fire which prevents a liquid falling out and coming out, once a liquid reaches predetermined hydrostatic pressure. In combination with a harder inhibiting film, same effect can be attained by using the pressure valve 515 which makes a free flow of a liquid possible above predetermined pressure.
[0072]
In form of a restraint means another again, a liquid with high viscosity is arranged to the free surface of the topmost part of the liquid of the reservoir 10. This controls formation of a surface wave, not blocking projection system PL but making it slip out of a liquid in crash. Naturally, the hyperviscous liquid must be [which are used in the space 10 / the liquid and nonmiscible].
[0073]
The further alternative of the liquid restraint means 510 about it is constituting from a mesh. The uppermost surface of a liquid is divided into two or more copies of area with small each in this method. The surface area for two or more of these copies is equal to the opening of a mesh, and since generation of a big surface wave by that cause is suppressed effectively, generating of the big surface wave which is made by resonance and checks a projection system is avoided. The effective pressure release mechanism which carries out projection system protection in the case of crash is brought about by a mesh by making possible the liquid flow which passes along the opening.
[Work example 6]
[0074]
The 6th embodiment shown in drawing 10 and drawing 11 is the same as the 1st embodiment

except for the contents of the description below. The 6th embodiment uses some of proposals in an above-mentioned embodiment.
[0075]
The immersion liquid 11 is confined in a field under a projection system in another embodiment by the seal member 12 which surrounded this and has been arranged under the last element of a projection system.
[0076]
A gas seal between the seal member 12 and the substrate W is formed from a feed port and a derivation port of three types. A seal member generally equips the derivation port 614, the feed port 615, and a pan with another feed port 617. these -- most near projection system PL -- the derivation port 614 -- the derivation port 614 -- the feed port 615 is immediately arranged further in the distance most from another feed port 617 and projection system PL outside. The feed port 615 changes from an air bearing by which gas supply is made to two or more derivation holes 620 in the surface of the seal member 12 facing the substrate W via the annular chamber 622. A role of both making possible a flow of air to derivation port 614 direction which helps for power of air of slipping out of the derivation port 620 to carry out the seal of the immersion liquid confined in a local field under projection system PL to a thing of weight of the seal member 12 for which a portion is supported at least is made. The purpose of the chamber 622 is for the separate gas supply orifice 625 to supply gas by a uniform pressure in the derivation hole 620. A diameter is about 0.25 mm and the derivation hole 620 has about 54 derivation holes 620. even if there is a difference of a size of order in flow restrictions between the derivation hole 620 and the chamber 622 and this is the small number 625, i.e., one main supply orifice, -- the derivation hole 620 -- a uniform outflow from all is enabled.
[0077]
The gas which escapes from the derivation hole 620 and comes out flows into both the inside and the outside radiately. The air which flows inside radiately from the derivation port 614 is effective in forming the seal between a seal member and the substrate W. However, when the flow of air was further brought about by the further feed port 617, it turned out that a seal is improved. The passage 630 is connected with the gas source, for example, the open air. The flow inside [radiate] the air from the feed port 615 is effective in drawing gas further toward the derivation port 614 from the further feed port 617.
[0078]
It is made for the ceiling flow of the edge of the innermost part of the slot 633 and the gas between the derivation ports 614 to be homogeneity certainly in the whole periphery. [slot / which was established in the end (not being a continuous separate feed port) of the passage 630 / 633 / annular] Generally width is 2.5 mm and a slot has the same height.
[0079]
A radius which is illustrated is brought about and the edge 635 of the innermost part of the slot 633 makes possible the smooth flow of the gas which goes to the derivation port 614 through the passage 630.
[0080]
In the derivation port 614, although height is only about 0.7 mm, width has the 6 to 7-mm continuous slot 640 again. About 90-degree sharp edge is brought about, and the edge 642 of the outermost part of the slot 640 is accelerated so that the flow of gas, especially the flow of the gas from the further feed port 630 may heighten the effect of a gas seal by it. The slot 640 has two or more derivation holes 645 which are connected with the annular chamber 647 and which are therefore connected with the separate derivation passage 649. In two or more derivation holes 645, a diameter is about 1 mm and, thereby, the waterdrop which passes through the derivation hole 645 is subdivided by smaller waterdrop.
[0081]
It is possible to adjust the liquid removing effect of the seal member 12 with the regulating valve 638 connected with the further feed port 617. The valve 638 is effective in adjustment of the flow passing through the further feed port 617, and this changes the liquid removing effect of the gas seal passing through the derivation port 614.

[0082]
The diameter of all of a seal member is an about 100-mm thing.
[0083]
Drawing 11 is a top view of the seal member bottom of drawing 10. As shown in a figure, the feed port 615 is provided as two or more separate introductory holes 620. Since the slot as an air bearing has the capability (based on the compressible characteristic of gas) for change to be set up in such a system, this has the strong point in the feed port 615 of a main to using a slot. In the introductory hole 620 of a small diameter, since the gas in it is the amount of low, it is seldom afflicted by the problem produced with the capability.
[0084]
The further feed port 617 of form of the slot 633 may be used in order to make possible a flow of gas which continues in all the circumferences of the seal member 12 which were not necessarily possible, when using only the separate introductory hole 620. Supplying the derivation port 645 as a separate component does not pose a problem by supplying the effective slot 640 like the chambers 647 and 622 stabilizing a flow.
[0085]
A feed port of a liquid is not shown in the seal member 12 of drawing 10 and drawing 11. A liquid is supplied in a method shown in the above-mentioned embodiment, and a similar way, or derivation ON of some liquids is carried out as the European patent application number 03256820.No. 6 and 03256809.9 are indicated.
[Work example 7]
[0086]
The 7th embodiment is below similar to the 6th embodiment except for the contents of the description. Drawing 12 is a top view of drawing 11 and the seal member 12 similar bottom. In drawing 12, although the further feed port as shown in the 6th embodiment is not established in the seal member 12, adding arbitrarily is also possible.
[0087]
The seal member 12 of the 7th embodiment is formed of the introductory hole 720, and comprises the same gas bearing 715 as the design by the 6th whole embodiment. The feed port 714 comprises the annular slot 740 which has only the two passages 745 and 747 led to a gas source and a vacuum source, respectively. The flow of the high-speed gas from a gas source to the vacuum source which was connected with the passage 745 by this method and which was connected with the passage 747 is brought about. It becomes possible to drain immersion liquid more effectively by the flow of this high-speed gas. Dispersion of the flow by the bouncing motion of the seal member 12 on the substrate W or the basis of the leakage of others in the surface does not affect the pressure of the vacuum chamber which gives precompression to a gas bearing by making the flow of the vacuum more greatly restricted in the vacuum chamber.
[Work example 8]
[0088]
The 8th embodiment explains in relation with drawing 14, and is the same as the first embodiment except for the contents of the description below.
[0089]
The 8th embodiment has the seal member 12 provided with the feed port 815 and the derivation port 814 like the first embodiment so that it may understand in drawing 14. However, it is arranged by the bottom of the derivation port 14, or the slightly radiate outside of this so that the gas jet which gathers the speed of the gas on the field of the substrate W may be made, and another feed port 817 is established [**s] in it, and immersion liquid is more effectively removed by it from the surface of the substrate W. The further feed port 817 has an exit brought about by the nozzle led to projection system PL toward the substrate W at the angle which goes to the radiate inside. The laminar flow (Reynolds number is about 300) between the feed port 815 and the derivation port 814 which cannot follow and cannot remove the last several micrometers liquid film from water and which has a velocity distribution of the shape of simple radiation at the zero speed on a substrate face is improved. It is because the gas which has more nearly high-speed air velocity is enabled to contact a substrate face by the further feed

port 817.
[0090]
the nozzle exit of drawing 14 to the further feed port 817 -- the radiate outside of the derivation port 814 -- however, it turns out that it is provided near the derivation port 814 rather than the feed port 815.
[Work example 9]
[0091]
The 9th embodiment is shown in drawing 15 and drawing 16, and this is the same as that of the first embodiment except for the contents of the description below.
[0092]
In the 9th embodiment, the mouth of the derivation port 914 in the bottom of the seal member which faces the substrate W is corrected so that the speed of the air into the derivation port 914 may be gathered. This can be reached by reducing the size of the mouth of the feed port 914, maintaining the passage of the derivation port 914 at the same size. This is attained by providing a smaller mouth by elongating the material of the seal member 12 toward the center of a passage, and forming the additional component 940 to the outside, and the additional component 950 to the inside. The additional component 940 to the outside is smaller than the additional component 950 to the inside, and its gap between these two components 940 and 950 is about 20 times as small as the remaining portion of the derivation port 914. The width of a mouth is about 100 to 300 micrometers.
[0093]
In drawing 16, further another form of the 9th embodiment is shown and the further feed port 917 similar to the feed port 817 in the 8th embodiment is formed here. However, the further feed port 917 brings about a jet almost parallel to the field of the substrate W in this case, and the gas which goes into the mouth of the derivation port 914 by that cause is accelerated.
[Work example 10]
[0094]
The 10th embodiment is shown in drawing 17 and this example is the same as that of the 1st embodiment except for the contents of the description below.
[0095]
In the 10th embodiment, liquid removal efficiency is improved by gathering the gas velocity on the surface of the substrate W according to the same principle as the 8th embodiment. The gas which comes out from the feed port 1015 and moves to the radiate inside toward the derivation port 1014 passes through the bottom of the annular slot 1018. The effect of a slot is that gas goes into the slot in the radiate outermost part, and comes out in the direction of the substrate W with an angle in a radiate medial surface so that it may illustrate. It follows and the increase of the speed of the gas on the surface of the substrate W and liquid removal efficiency are improved at the entrance to the derivation port 1014.
[0096]
Even if it is a future of which embodiment, it is some of other embodiments, or it is clear that it is usable with all futures.
[0097]
As mentioned above, although an embodiment of this invention was described in detail, it is clear for a person skilled in the art that shape can be taken by other methods, without deviating from the range of this invention. This detailed explanation is not the intention which restricts this invention.
[Brief Description of the Drawings]
[0098]
[Drawing 1]The lithography projection apparatus in the embodiment of this invention is shown.
[Drawing 2]The liquid reservoir of the 1st embodiment of this invention is shown.
[Drawing 3]It is an enlarged drawing of the portion of the liquid reservoir of the 1st embodiment of this invention.
[Drawing 4]The liquid reservoir of the 2nd embodiment of this invention is shown.
[Drawing 5]It is an enlarged drawing of the portion of the liquid reservoir of the 2nd embodiment

of this invention.
[Drawing 6]It is an enlarged drawing of the liquid reservoir of the 3rd embodiment of this invention.
[Drawing 7]The liquid reservoir of the 4th embodiment of this invention is shown.
[Drawing 8]It is an enlarged drawing of the portion of the liquid reservoir of the 4th embodiment of this invention.
[Drawing 9]The liquid reservoir of the 5th embodiment of this invention is shown.
[Drawing 10]The liquid reservoir of the 6th embodiment of this invention is shown.
[Drawing 11]It is a top view of the seal member bottom of the 6th embodiment.
[Drawing 12]It is a top view of the seal member bottom of the 7th embodiment.
[Drawing 13]It is a sectional view of the liquid reservoir of the 7th embodiment.
[Drawing 14]It is a sectional view of the liquid reservoir of the 8th embodiment.
[Drawing 15]It is a sectional view of the liquid reservoir of the 9th embodiment.
[Drawing 16]It is a sectional view of the liquid reservoir of the modification mode of 9th another embodiment.
[Drawing 17]It is a sectional view of the liquid reservoir of the 10th embodiment.

[Translation done.]

(19) 日本国特許庁(JP)　(12) 公開特許公報(A)　(11) 特許出願公開番号
特開2004-289126
(P2004-289126A)
(43) 公開日 平成16年10月14日(2004.10.14)

(51) Int.Cl.⁷	F I			テーマコード（参考）
H01L 21/027	H01L	21/30	515D	5F046
G03F 7/20	G03F	7/20	521	
	H01L	21/30	516F	

審査請求 有　請求項の数 29　OL　外国語出願　（全 54 頁）

(21) 出願番号　特願2003-417259 (P2003-417259)
(22) 出願日　平成15年11月11日 (2003.11.11)
(31) 優先権主張番号　02257822.3
(32) 優先日　平成14年11月12日 (2002.11.12)
(33) 優先権主張国　欧州特許庁 (EP)
(31) 優先権主張番号　03252955.4
(32) 優先日　平成15年5月13日 (2003.5.13)
(33) 優先権主張国　欧州特許庁 (EP)

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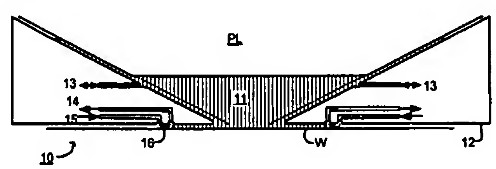
最終頁に続く

(54)【発明の名称】リソグラフィ装置およびデバイス製造方法

(57)【要約】
【課題】ステージ動作の間に加速される必要のある液体の量を最小限にして、基板と投影システム間のスペースを液体で満たしたリソグラフィ投影装置を提供することを目的とする。
【解決手段】リソグラフィ投影装置において、投影システムの最終素子とリソグラフィ投影装置の基板テーブル間のスペースをシール部材にて囲む。該シール部材と該基板の面間においてガスシールが形成され、このスペースに液体を封じ込める。
【選択図】図２



【特許請求の範囲】
【請求項１】
　－　放射線の投影ビームを供給する放射線システムと、
－　所望するパターンに従って投影ビームをパターン化するパターニング手段を支持する支持構造と、
－　基板を保持する基板テーブルと、
－　パターン化されたビームを基板の目標部分に投影する投影システムと、
－　該投影システムの最終素子と該基板間のスペースを少なくとも部分的に液体で満たす液体供給システムとから成るリソグラフィ投影装置において、該液体供給システムは、
－　上記投影システムの最終素子と上記基板テーブル間の上記スペースの少なくとも境界の部分に沿って伸長したシール部材と、
－　該シール部材と該基板の表面間においてガスシールを形成するガスシール手段とにより構成されることを特徴とするリソグラフィ投影装置。
【請求項２】
　上記のガスシール手段は、上記基板上にて上記シール部材を支持するガスベアリングであることを特徴とする請求項１に記載の装置。
【請求項３】
　上記のガスシール手段は、上記基板に対向した上記シール部材の面に形成されたガス導入口および第一ガス導出口と、該導入口に加圧下にてガスを供給する手段と、該第一ガス導出口からガスを抽出する真空手段とにより構成されていることを特徴とする請求項１または２に記載の装置。
【請求項４】
　ガスソースに連結した、上記第一ガス導出口と上記ガス導入口間に配置されたさらなる導入口をさらに備えていることを特徴とする請求項３に記載の装置。
【請求項５】
　上記のさらなる導入口は、上記基板に面した上記シール部材の面における連続した環状の溝から成ることを特徴とする請求項４に記載の装置。
【請求項６】
　上記の溝の放射状の最も内側のコーナーは半径を有することを特徴とする請求項５に記載の装置。
【請求項７】
　上記の第一ガス導出口は、上記基板に面した上記シール部材の面における連続した環状の溝から成ることを特徴とする請求項３から６のいずれか１項に記載の装置。
【請求項８】
　上記の第一ガス導出口および／または上記のガス導入口は、上記供給の手段と上記真空手段間のそれぞれのチャンバと、上記表面における導入口あるいは導出口の開口から成り、チャンバは該開口よりも低い流量制限をもたらすことを特徴とする請求項３から７のいずれか１項に記載の装置。
【請求項９】
　上記のガス導入口は、上記基板に面した上記シール部材の面における一続きの別々の開口からなることを特徴とする請求項３から８のいずれか１項に記載の装置。
【請求項１０】
　ガス導入口の領域にガスの流れを均等に分配するよう、該ガス導入口に多孔質部材が配置されることを特徴とする請求項３から９のいずれか１項に記載の装置。
【請求項１１】
　上記のガスシール手段は、上記基板に対向した上記シール部材の上記面に形成された第二ガス導出口をさらに備え、上記第一ガス導出口および該第二ガス導出口は上記ガス導入口の両側に形成されることを特徴とする請求項３から１０のいずれか１項に記載の装置。
【請求項１２】
　上記面の残り部分に対して、上記第一ガス導出口と上記ガス導入口間における上記面の

部分のレベルを変える手段をさらに備えていることを特徴とする請求項３から１１のいずれか１項に記載の装置。

【請求項１３】

該装置は、上記面の残り部分に対して、上記第一ガス導出口と上記光軸に最も近い面のエッジ間における上記面の部分のレベルを変える手段をさらに備えていることを特徴とする請求項３から１２のいずれか１項に記載の装置。

【請求項１４】

上記のガスシール手段は、上記第一ガス導出口よりも投影システムの光軸に近くに位置して、上記面に形成されるチャネルを備えていることを特徴とする請求項３から１３のいずれか１項に記載の装置。

【請求項１５】

上記のチャネルは第二ガス導入口であることを特徴とする請求項１４に記載の装置。

【請求項１６】

上記のチャネルは、上記スペースにおける液面の上の環境に開いていることを特徴とする請求項１５に記載の装置。

【請求項１７】

上記のガス導入口は、上記投影システムの光軸から、上記第一ガス導出口よりもさらに外側に配置されていることを特徴とする請求項３から１６のいずれか１項に記載の装置。

【請求項１８】

上記のガス導入口およびガス導出口は、それぞれ該基板に対向した該シール部材の該面における溝と、間隔をとって配置された該溝に導かれる複数の導管とから成ることを特徴とする請求項３から１７のいずれか１項に記載の装置。

【請求項１９】

上記シール部材の上記面と、上記基板および／または上記基板のトポロジー間の距離を測定するセンサーをさらに備えていることを特徴とする請求項１から１８のいずれか１項に記載の装置。

【請求項２０】

上記シール部材と上記基板間の剛性、および／または、上記シール部材と上記基板間の距離を調整するために、上記ガスシール手段におけるガスの圧力を調節する調整手段をさらに備えていることを特徴とする請求項１から１９のいずれか１項に記載の装置。

【請求項２１】

毛管作用によりギャップ内に液体を引き込むよう、かつ／またはガスシール部材からのガスが上記投影システムと上記基板間の上記スペースに入るのを防ぐよう、上記シール部材と上記ガスシール手段の内側にある該基板の面との間のギャップは小さいことを特徴とする前記請求項のいずれか１項に記載の装置。

【請求項２２】

上記シール部材は、上記投影システムと上記基板間の上記スペースを囲んで閉ループを形成することを特徴とする前記請求項のいずれか１項に記載の装置。

【請求項２３】

－　放射線の投影ビームを供給する放射線システムと、

－　所望するパターンに従って投影ビームをパターン化するパターニング手段を支持する支持構造と、

－　基板を保持する基板テーブルと、

－　パターン化されたビームを基板の目標部分に投影する投影システムと、

－　該投影システムの最終素子と該基板間のスペースを少なくとも部分的に液体で満たす液体供給システムとから成るリソグラフィ投影装置において、該スペースはダクトを通して液体リザーバと液体にて連結を行っており、流体の流れ方向に垂直な面における該ダクトの最小断面領域は少なくとも、

【数１】

$$\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{\max}t_{\min}}\right)^{1/2}$$

となり、△Ｖは時間 t_{min} 内に該スペースから取り除かれなくてはならない液体の量であり、Ｌはダクト長であり、ηは該スペースにおける液体の粘度であり、そして ΔP_{max} は該最終素子にかかる最大許容圧力であることを特徴とするリソグラフィ投影装置。

【請求項２４】

上記スペースに液体があるときに、該液体が自由な上面を有さないように該スペースが密閉されていることを特徴とする請求項２３に記載の装置。

【請求項２５】

－　放射線の投影ビームを供給する放射線システムと、

－　所望するパターンに従って投影ビームをパターン化するパターニング手段を支持する支持構造と、

－　基板を保持する基板テーブルと、

－　パターン化されたビームを基板の目標部分に投影する投影システムと、

－　該投影システムの最終素子と該基板間のスペースを少なくとも部分的に液体で満たす液体供給システムとから成るリソグラフィ投影装置において、該液体供給システムはさらに、該液体供給システムにおける液体の最上面において、波の発生を抑え、かつ、圧力解除手段を含む抑制手段を備えていることを特徴とするリソグラフィ投影装置。

【請求項２６】

上記の抑制手段は可とう性のある膜からなることを特徴とする請求項２５に記載の装置。

【請求項２７】

上記の抑制手段はメッシュからなり、上記液体の上記最上面の最大領域がメッシュの開口に等しいことを特徴とする請求項２５または２６に記載の装置。

【請求項２８】

上記の抑制手段は安全弁を備え、特定の圧力により液体を通過させることを特徴とする請求項２５、２６、または２７に記載の装置。

【請求項２９】

上記の抑制手段は、上記液体と非混和性である高粘度の液体であることを特徴とする請求項２５に記載の装置。

【発明の詳細な説明】

【技術分野】

【０００１】

本発明は、

－　放射線の投影ビームを供給する放射線システムと、

－　所望するパターンに従って投影ビームをパターン化するパターニング手段を支持する支持構造と、

－　基板を保持する基板テーブルと、

－　パターン化されたビームを基板の目標部分に投影する投影システムと、

－　該投影システムの最終素子と該基板間のスペースを少なくとも部分的に液体で満たす液体供給システムとから成るリソグラフィ投影装置に関する。

【背景技術】

【０００２】

本明細書において使用する「パターニング手段」なる用語は、入射する放射線ビームに、基板の目標部分に作り出されるべきパターンと一致するパターン化断面を与えるために使用し得る手段に当たるものとして広義に解釈されるべきである。また、「ライトバルブ

」なる用語もこうした状況において使用される。一般的に、上記のパターンは、集積回路や他のデバイス（以下を参照）であるような、デバイスにおいて目標部分に作り出される特別な機能層に相当する。そのようなパターニング手段には以下が含まれる。すなわち、
－　マスク。マスクの概念はリソグラフィにおいて周知のものであり、これには、様々なハイブリッドマスクタイプのみならず、バイナリマスク、レベンソンマスク、減衰位相シフトマスクといったようなマスクタイプも含まれる。放射線ビームにこのようなマスクを配置することにより、マスクに照射する放射線の、マスクパターンに従う選択的透過（透過性マスクの場合）や選択的反射（反射性マスクの場合）を可能にする。マスクの場合、その支持構造は一般的に、入射する放射線ビームの所望する位置にマスクを保持しておくことが可能であり、かつ、必要な場合、ビームに対して運動させることの可能なマスクテーブルである。
－　プログラマブルミラーアレイ。このようなデバイスの一例として、粘弾性制御層および反射面を有するマトリクスアドレス可能面があげられる。こうした装置の基本的原理は、（例えば）反射面のアドレスされた領域は入射光を回折光として反射するが、アドレスされていない領域は入射光を非回折光として反射するといったことである。適切なフィルタを使用することにより、回折光のみを残して上記非回折光を反射ビームからフィルタすることが可能である。この方法において、ビームはマトリクスアドレス可能面のアドレスパターンに従ってパターン形成される。プログラマブルミラーアレイのまた別の実施形態では小さな複数のミラーのマトリクス配列を用いる。そのミラーの各々は、適した局部電界を適用することによって、もしくは圧電作動手段を用いることによって、軸を中心に個々に傾けられている。もう一度言うと、ミラーはマトリクスアドレス可能であり、それによりアドレスされたミラーはアドレスされていないミラーとは異なる方向に入射の放射線ビームを反射する。このようにして、反射されたビームはマトリクスアドレス可能ミラーのアドレスパターンに従いパターン形成される。必要とされるマトリクスアドレッシングは適切な電子手段を用いて実行される。前述の両方の状況において、パターニング手段は１つ以上のプログラマブルミラーアレイから構成可能である。ここに参照を行ったミラーアレイに関するより多くの情報は、例えば、米国特許第ＵＳ５，２９６，８９１号および同第ＵＳ５，５２３，１９３号、並びに、ＰＣＴ特許種出願第ＷＯ９８／３８５９７および同ＷＯ９８／３３０９６に開示されているので詳細は、これらの内容を参照されたい。プログラマブルミラーアレイの場合、上記支持構造は、例えばフレームもしくはテーブルとして具体化され、これは必要に応じて、固定式となるか、もしくは可動式となる。
－　プログラマブルＬＣＤアレイ。このような構成の例が米国特許第ＵＳ５，２２９，８７２号に開示されているので詳細は、この内容を参照されたい。上記同様、この場合における支持構造も、例えばフレームもしくはテーブルとして具体化され、これも必要に応じて、固定式となるか、もしくは可動式となる。簡潔化の目的で、本文の残りを、特定の箇所において、マスクおよびマスクテーブルを必要とする例に限定して説明することとする。しかし、こうした例において論じられる一般的な原理は、既に述べたようなパターニング手段のより広範な状況において理解されるべきである。
【０００３】
リソグラフィ投影装置は例えば、集積回路（ＩＣ）の製造において使用可能である。この場合、パターニング手段はＩＣの個々の層に対応する回路パターンを生成する。そして、放射線感光原料（レジスト）の層が塗布された基板（シリコンウェハ）上の目標部分（例えば１つあるいはそれ以上のダイから成る）にこのパターンを像形成することが出来る。一般的に、シングルウェハは、投影システムを介して１つずつ順次照射される近接目標部分の全体ネットワークを含んでいる。マスクテーブル上のマスクによるパターニングを用いる現在の装置は、異なる２つのタイプのマシンに区分される。リソグラフィ投影装置の一タイプでは、全体マスクパターンを目標部分に１回の作動にて露光することによって各目標部分が照射される。こうした装置は一般的にウェハステッパと称されている。ステップアンドスキャン装置と称される別の装置では、所定の基準方向（「スキャニング」方向）にマスクパターンを投影ビームで徐々にスキャニングし、これと同時に基板テーブル

をこの方向と平行に、あるいは反平行にスキャニングすることにより、各目標部分が照射される。一般的に、投影装置は倍率係数Ｍ（一般的に、＜１）を有することから、基板テーブルが走査される速度Ｖは、マスクテーブルが走査される速度の係数Ｍ倍となる。ここに記載を行ったリソグラフィデバイスに関するさらなる情報は、参考までに記載を行うと、例えば、米国特許第ＵＳ６，０４６，７９２号から得ることが出来る。

【０００４】

リソグラフィ投影装置を使用する製造工程において、パターン（例えばマスクにおける）は少なくとも部分的に放射線感光材（レジスト）の層で覆われた基板上に像形成される。この像形成ステップに先立ち、基板は、プライミング、レジスト塗布、およびソフトベークといったような各種の工程を経る。露光後、基板は、ポストベーク（ＰＥＢ）、現像、ハードベーク、および像形成フューチャの測定／検査といったような他の工程を通る。この工程の配列は、例えばＩＣといったような素子の個々の層をパターン化するための基準として使用される。このようなパターン形成された層は、それから、全て個々の層を仕上げる目的である、エッチング、イオン注入（ドーピング）、メタライゼーション、酸化、化学機械的研磨等といった種々のプロセスを経る。数枚の層が必要とされる場合には、全体工程、もしくはその変形をそれぞれの新しい層に繰り返す必要がある。最終的に、素子のアレイが基板（ウェハ）上に形成される。次に、これらの素子はダイシングやソーイングといったような技法で相互より分離される。それから個々の素子は、キャリアに装着されたり、ピンに接続されたりし得る。こうした工程に関するさらなる情報は、１９９７年にマグローヒル出版会社より刊行された、Ｐｅｔｅｒ ｖａｎ Ｚａｎｔ著、「マイクロチップ製造：半導体処理に対する実用ガイド」という名称の書籍（“Ｍｉｃｒｏｃｈｉｐ Ｆａｂｒｉｃａｔｉｏｎ：Ａ Ｐｒａｔｉｃａｌ Ｇｕｉｄｅ ｔｏ Ｓｅｍｉｃｏｎｄｕｃｔｏｒ Ｐｒｏｃｅｓｓｉｎｇ”）の第３版、ＩＳＢＮ０－０７－０６７２５０－４に記載されているので詳細はこの内容を参照されたい。

【０００５】

簡潔化の目的で、これより投影システムを「レンズ」と称するものとする。しかし、この用語は、例えば屈折光学システム、反射光学システム、および反射屈折光学システムを含むさまざまなタイプの投影システムを網羅するものとして広義に解釈されるべきである。放射線システムはまた、放射線の投影ビームの誘導、成形、あるいは制御を行う、こうした設計タイプのいずれかに応じて稼動する構成要素も備えることが出来る。こうした構成要素もまた以降において集約的に、あるいは単独的に「レンズ」と称する。さらに、リソグラフィ装置は２つあるいはそれ以上の基板テーブル（および、あるいは２つもしくはそれ以上のマスクテーブル）を有するタイプのものである。このような「多段」デバイスにおいては、追加のテーブルが並列して使用される。もしくは、１つ以上の他のテーブルが露光に使用されている間に予備工程が１つ以上のテーブルにて実行される。例えば、参考までに、デュアルステージリソグラフィ装置について、米国特許第ＵＳ５，９６９，４４１号および国際特許出願第ＷＯ９８／４０７９１号において記載がなされている。

【０００６】

投影システムの最終素子と基板間のスペースを満たすように、例えば水といったような、比較的高い屈折率を有する液体にリソグラフィ投影装置における基板を浸すことが提案されている。これにおけるポイントは、露光放射線は液体においてより短い波長を有するため、より小さいフィーチャを結像可能にすることである。（液体の効果でシステムにおける有効ＮＡも増すと考えられる。）

【０００７】

しかし、基板テーブルを液体に浸すことは、走査露光中に加速されなくてはならない多量の液体があることを意味する。これは追加の、あるいはより強力なモータを必要とし、液体における乱流が望ましからざる、かつ予測し得ない影響をもたらす。

【０００８】

リソグラフィ投影装置に液体を有することに関していくつかの困難がある。例えば液体を流出させることは、干渉計により干渉することによって、かつ、リソグラフィ投影装置

においてビームを真空に保つ必要がある場合、その真空を破壊することによって問題を生じる。さらには、適切な予防策がとられないままに液体はかなりの割合で使用される。

【０００９】

液浸リソグラフィに関連するさらなる問題に、液体の深度を一定に保つことにおける困難さや、結像位置、すなわち最終投影システム素子の下への基板の搬送、またその結像位置からの搬送における困難さが含まれる。また、液体の汚染（液体に溶解した化学物質による）、および液体の温度の上昇は達成可能な結像品質に有害な影響を及ぼす。

【００１０】

何らかの理由による、コンピュータの故障、電源障害、あるいは装置の制御ロスの際に、特に投影システムの光学素子を保護するための工程を実行する必要がある。また、装置の他の構成要素に液体がこぼれるのを防止する工程をもうける必要がある。

【００１１】

液体供給システムが、液体が自由面を有する場合において使用される場合、液体供給システムに加えられる力によりその自由面に波が発生するのを防ぐための工程を実行する必要がある。波は動作基板から投影システムに振動を伝えうる。

【００１２】

国際特許出願番号ＷＯ９９／４９５０４号において、液体が投影レンズとウェハ間のスペースに供給されるリソグラフィ装置が開示されている。ウェハがレンズの下でＸ方向に走査されるとき、液体はレンズの＋Ｘサイドにて供給され、－Ｘサイドで取り上げられる。

【発明の開示】

【発明が解決しようとする課題】

【００１３】

本発明は、ステージ動作の間に加速される必要のある液体の量を最小限にして、基板と投影システム間のスペースを液体で満たしたリソグラフィ投影装置を提供することを目的とする。

【課題を解決するための手段】

【００１４】

本目的並びに他の目的は、冒頭の段落にて特定したようなリソグラフィ投影装置において、本発明に従い達成される。ここで、上記の液体供給システムは、

－　上記投影システムの最終素子と上記基板テーブル間の上記スペースの少なくとも境界の部分に沿って伸長したシール部材と、

－　該シール部材と該基板の表面間においてガスシールを形成するガスシール手段とから構成される。

【００１５】

ガスシール手段はこのようにしてシール部材と基板間において非接触シールを形成することから、例えば走査露光中に、投影システムの下で基板が動作するときであっても、液体は投影システムの最終素子と基板間のスペースに封じ込まれる。

【００１６】

シール部材は、スペースを囲む、円形、長方形、もしくは他の形状のいずれかの閉ループ形状をなすか、あるいは、例えばＵ型の形状、またはスペースの一方サイドに沿って伸長しただけの閉じていない形状も可能である。シール部材が閉じていない場合、基板が投影システムの下で走査されるとき、シール部材は液体を閉じ込めるように配置される。

【００１７】

好ましくは、ガスシール手段は、該シール部材を支持するガスベアリングである。これは、液体供給システムの同一部分が、ベアリングと、そして、投影システムの最終素子と基板間のスペースにおける液体のシーリングの両方に使用可能であり、それによりシール部材の複雑さと重量を減じるという長所を有する。また、真空環境においてのガスベアリングの使用から得られた以前の経験を生かすことが出来る。

【００１８】

好ましくは、ガスシール手段は、上記基板に対向した該シール部材の面に形成されたガス導入口および第一ガス導出口と、該導入口に加圧下にてガスを供給する手段と、該第一ガス導出口からガスを抽出する真空手段とにより構成される。さらに望ましくは、ガス導入口は上記投影システムの光軸から該第一ガス導出口よりもさらに外側に配置される。このようにしてガスシールにおけるガスの流れは内側に向き、最も効果的に液体を封じ込める。この場合、ガスシール手段は有利に、基板に対向したシール部材の面に形成された第二ガス導出口をさらに備え、第一ガス導出口および第二ガス導出口はガス導入口の両側に形成される。第二ガス導出口は、ガス導入口からシール部材を囲む環境に抜け出すガスを最小限に抑えることを可能にする。よって、抜け出る、干渉計により干渉する、あるいはリソグラフィ装置における真空を低下させるといったガスのリスクは最小限に抑えられる。

【００１９】

液体供給システムは、シール部材の面と、基板および／または基板の最上面のトポロジー間の距離を測定するセンサーをも備えている。このようにして調整手段は、例えばガスシール手段をフィードフォワード方式あるいはフィードバック方式にて調整することでシール部材の面と基板間の距離を変えるために使用され得る。

【００２０】

該装置は、第一ガス導出口と光軸に最も近い面のエッジとで該シール部材の該面の部分のレベルを面の残り部分に対して変える手段をさらに備えている。これは、スペース内に液体を封じ込める圧力の調整が導入口の下の圧力の調整とは別になされるようにすることで、スペース内に液体を保持する力のバランスを乱すことなく基板上のシール部材の高さを調整することが可能である。これを可能にするまた別の方法は、第一ガス導出口または第二ガス導出口とガス導入口間の面の部分のレベルを面の残り部分に対して変えるための手段を使用することである。これら３つのシステムはどのような組み合わせでも使用可能である。

【００２１】

ガスシール手段のシーリング機能とベアリング機能を分けるまた別の方法は、第一ガス導出口よりも投影システムの光軸の近くに位置して、シール部材の面に形成されるチャネルを設けることである。このチャネルの圧力は、スペース内に液体を封じ込めるように変えることが可能である一方、ガス導入口およびガス導出口は基板上のシール部材の高さを変えるために使用可能であることから、これらはシール部材を支持するためにのみ作用し、シーリング機能は、たとえあったとしても、ほんのわずかでしかない。

【００２２】

さらに有利なフューチャは、ガスの流れをガス導入口の領域に均等に分配する目的でガス導入口に配置される多孔質部材である。

【００２３】

これは、ガス導入口およびガス導出口を形成するのに好都合であり、ガス導入口の各々は該基板に対向した該シール部材の該面における溝と、間隔をとって配置された該溝に導かれる複数の導管とから成る。

【００２４】

また、毛管作用でギャップ内に液体を引き込むよう、かつ／あるいはガスシール部材からのガスが該スペースに入るのを防止するよう、該シール部材と該ガスシール手段の内側にある該基板の面との間のギャップは小さいことが望ましい。シール部材の下に液体を引き込む毛管作用とそれを押し出すガスの流れとの間のバランスによってとりわけ安定したシールを形成する。

【００２５】

基板と投影システム間のスペースを液体で満たし、基板と投影システム間の外乱の伝わりを最小限におさえるリソグラフィ投影装置を提供することをさらなる目的とする。

【００２６】

本目的並びに他の目的は、冒頭の段落で特定したようなリソグラフィ装置において本発

明に従って達成される。ここで、該スペースはダクトを通して液体リザーバと液体にて連結を行っており、流体の流れ方向に垂直な面における該ダクトの最小断面領域は少なくとも、

【数１】

$$\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$$

となり、△Ｖは時間t_{min}内に該スペースから取り除かれなくてはならない液体の量であり、Ｌはダクト長であり、ηは該スペースにおける液体の粘度であり、そしてΔP_{max}は該最終素子にかかる最大許容圧力である。

【００２７】

この装置は、液体が、波の発生する大きな自由面を有さないように、完全に抑制されることができるという長所を有する。すなわち、スペースあるいはリザーバは最上部でエンクローズされ、リザーバは液体で満たされている。これは、所定の時間内（実験的に計測されたクラッシュの時間）にダクトを通して流出可能な流体の量が、装置のクラッシュの際に投影システムの最終素子への損傷が回避され得るほど十分に多いことから、スペース内の圧力が損傷を発生させるレベルに達する前にダクトを通り液体が抜け出すことが出来るからである。シール部材が最終素子に対して動作するとき、液体は抜け出さなくてはならない。そうしないと、シール部材に対する最終素子の相対動作の間に最終素子にかかる静水圧が最終素子に損傷を与えることとなる。

【００２８】

本発明の別の態様において、冒頭の段落において特定したようなリソグラフィ装置が提供される。ここで、液体供給システムはさらに、該液体供給システムにおける液体の最上面において、波の発生を抑える、かつ、圧力解除手段を含む抑制手段を備える。

【００２９】

このようにして抑制手段が液体の最上面と接触することにより波の発生が抑えられる。しかし、クラッシュの際に最終素子への損傷を回避するため、なおかつ液体はこのスペースから抜け出すことが出来る。

【００３０】

抑制手段を提供する一つの方法は可とう性のある膜を通すか、あるいはスペース内の液体と非混和性の高粘度の液体をスペース内の液体最上面に置くことである。これらの各場合において、抑制手段の可とう性により圧力解除機能がもたらされる。

【００３１】

本発明の別の態様において、

－　放射線感光材料の層により少なくとも部分的に覆われた基板を提供するステップと、

－　放射線システムを用いて放射線の投影ビームを供給するステップと、

－　パターニング手段を用いて投影ビームのその断面にパターンを与えるステップと、

－　放射線感光材料の層の目標部分に放射線のパターン化されたビームを投影するステップと、

－　基板と、上記投影ステップにおいて使用される投影システムの最終素子間のスペースを満たすように液体を供給するステップとからなるデバイス製造方法が提供され、

－　該スペースの少なくとも境界の部分に沿って伸長したシール部材と該基板の表面間においてガスシールを形成するか、あるいは、

－　ダクトを通して該スペースと液体にて連結する液体リザーバを提供するかのいずれかであって、

－　該ダクトは、

【数２】

$$\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{\max}t_{\min}}\right)^{1/2}$$

の液体の流れ方向に垂直な面において最小の断面領域を有しており、ここで、△Ｖは時間t_{min}内に該スペースから取り除かれなくてはならない液体の量であり、Ｌはダクト長であり、ηは該スペースにおける液体の粘度であり、そして△P_{max}は該最終素子上の最大許容圧力であることを特徴とし、あるいは、

－　抑制手段によって該液体の波の発生を抑制し、かつ、該液体の圧力を解除させることを特徴とする。

【００３２】

本発明による装置の使用法に関して、本文ではＩＣの製造において詳細なる参照説明を行うものであるが、こうした装置が他の多くの用途においても使用可能であることは明確に理解されるべきである。例えば、本発明による装置は、集積光学装置、磁気ドメインメモリ用ガイダンスおよび検出パターン、液晶ディスプレイパネル、薄膜磁気ヘッド等の製造に使用され得る。こうした代替的な用途においては、本文にて使用した「レチクル」、「ウェハ」、「ダイ」といった用語は、それぞれ「マスク」、「基板」、「目標部分」といった、より一般的な用語に置き換えて使用され得ることは当該技術分野の専門家にとって明らかである。

【００３３】

本明細書において使用した「放射線」および「ビーム」という用語は、イオンビームあるいは電子ビームといったような粒子ビームのみならず、紫外線（例えば、３６５ｎｍ、２４８ｎｍ、１９３ｎｍ、１５７ｎｍ、あるいは１２６ｎｍの波長を有する）を含むあらゆるタイプの電磁放射線を網羅するものである。

【００３４】

本発明の実施例についての詳細説明を、添付の図面を参照に、例示の方法においてのみ行うものとする。全図を通して同様部品には、同様の参照番号を含むものとする。

【実施例１】

【００３５】

図１は、本発明の独自の実施形態に基づくリソグラフィ投影装置を示したものである。この装置は、特別な本実施形態において放射線源ＬＡも備えた、放射線の投影ビームＰＢ（例えばＤＵＶ放射線）を供給する放射線システムＥｘ、ＩＬと、マスクＭＡ（例えばレクチル）を保持するマスクホルダーｗ備え、かつ、品目ＰＬに対して正確にマスクの位置決めを行う第一位置決め手段に連結を行った第一オブジェクト・テーブル（マスクテーブル）ＭＴと、基板Ｗ（例えば、レジスト塗布シリコンウェハ）を保持する基板ホルダを備え、かつ、品目ＰＬに対して正確に基板の位置決めを行う第二位置決め手段に連結を行った第二オブジェクト・テーブル（基板テーブル）ＷＴと、マスクＭＡの照射部分を、基板Ｗの目標部分Ｃ（例えば、１つあるいはそれ以上のダイから成る）に像形成する投影システム（「レンズ」）ＰＬ（例えば反射屈折レンズシステム）とにより構成されている。ここで示しているように、この装置は透過タイプ（すなわち透過マスクを有する）である。しかし、一般的には、例えば反射マスクを有する反射タイプのものも可能である。あるいは、本装置は、上記に関連するタイプであるプログラマブルミラーアレイといったような、他の種類のパターニング手段も使用可能である。

【００３６】

ソースＬＡ（例えばエキシマレーザー）は放射線のビームを作り出す。このビームは、直接的に、あるいは、例えばビームエキスパンダーＥｘといったようなコンディショニング手段を横断した後に、照明システム（照明装置）ＩＬに供給される。照明装置ＩＬは、ビームにおける強度分布の外部かつ／あるいは内部放射範囲（一般的にそれぞれ、σ－ｏｕｔｅｒおよびσ－ｉｎｎｅｒに相当する）を設定する調整手段ＡＭから成る。さらに、

照明装置ＩＬは一般的に積分器ＩＮおよびコンデンサＣＯといったような、他のさまざまな構成要素を備える。このようにして、マスクＭＡに照射するビームＰＢは、その断面に亘り所望する均一性と強度分布とを有する。

【００３７】

図１に関して、ソースＬＡはリソグラフィ装置のハウジング内にある（これは例えばソースが水銀ランプである場合に多い）が、しかし、リソグラフィ投影装置から離して配置することも可能であることを注記する。この場合、ソースＬＡが作り出す放射線ビームは（適した誘導ミラーにより）装置内に導かれる。この後者のシナリオでは、ソースＬＡがエキシマレーザーである場合が多い。本発明および請求項はこれら両方のシナリオを網羅するものである。

【００３８】

続いてビームＰＢはマスクテーブルＭＴ上に保持されているマスクＭＡに入射する。ビームＰＢはマスクＭＡを横断して基板Ｗの目標部分Ｃ上にビームＰＢの焦点を合わせるレンズＰＬを通過する。第二位置決め手段（および干渉計測手段ＩＦ）により、基板テーブルＷＴは、例えばビームＰＢの経路における異なる目標部分Ｃに位置を合わせるために正確に運動可能である。同様に、第一位置決め手段は、例えばマスクライブラリからマスクＭＡを機械的に検索した後に、あるいは走査運動の間に、ビームＰＢの経路に対してマスクＭＡを正確に位置決めするように使用可能である。一般的に、オブジェクト・テーブルＭＴおよびオブジェクト・テーブルＷＴの運動はロングストロークモジュール（粗動位置決め）およびショートストロークモジュール（微動位置決め）にて行われる。これについては図１に明示を行っていない。しかし、ウェハステッパの場合（ステップアンドスキャン装置とは対照的に）、マスクテーブルＭＴはショートストロークアクチュエータに連結されるだけであるか、あるいは固定される。

【００３９】

ここに表した装置は２つの異なるモードにて使用可能である。

－　ステップモードにおいて、マスクテーブルＭＴは基本的に静止状態に保たれている。そして、マスクの像全体が１回の作動（すなわち１回の「フラッシュ」）で目標部分Ｃに投影される。次に基板テーブルＷＴがｘ方向および／あるいはｙ方向にシフトされ、異なる目標部分ＣがビームＰＢにより照射され得る。

－　スキャンモードにおいて、基本的に同一シナリオが適用されるが、但し、ここでは、所定の目標部分Ｃは１回の「フラッシュ」では露光されない。代わって、マスクテーブルＭＴが、速度ｖにて所定方向（いわゆる「走査方向」、例えばｙ方向）に運動可能であり、それによってビームＰＢがマスクの像を走査する。これと同時に、基板テーブルＷＴが速度Ｖ＝Ｍｖで、同一方向あるいは反対方向に運動する。ここで、ＭはレンズＰＬの倍率（一般的にＭ＝１／４あるいは１／５）である。このように、解像度を妥協することなく、比較的大きな目標部分Ｃを露光することが可能となる。

【００４０】

図２は、投影システムと基板ステージ間における液体リザーバ１０を示したものである。液体リザーバ１０には、導入／導出ダクト１３を介して、例えば水であるような比較的高い屈折率を有する液体１１が満たされている。液体の効果は、投影ビームの放射線が空気や真空におけるよりも、液体にてより短い波長を有し、より小さいフィーチャの解像を可能にすることにある。投影システムの解像度限界は、とりわけ投影ビームの波長、およびシステムの開口数によって決定する。液体の存在も有効開口数を増すと考えられる。さらに、液体は固定の開口数で被写界深度を増すのに効果的である。

【００４１】

リザーバ１０は、投影システムのイメージフィールドのまわりに基板に対する非接触シールを形成しており、基板表面と投影システムの最終素子間のスペースをうめるように液体が閉じ込められている。リザーバは投影システムＰＬの最終素子の下で、これを囲んで配置されたシール部材１２から形成されている。液体が投影システムの下のシール部材１２内のスペースに入れられる。これでシール部材１２は投影システムの最終素子を少し超

えて伸長しており、液面は最終素子まで上がって液体のバッファがもたらされる。シール部材１２は、上端部で、投影システムのステップもしくはその最終素子に、好ましくきっちりと一致する内周を有しており、そして、例えば丸くても良い。底部において、内周は、これに限るわけではないが例えば長方形のイメージフィールドの形状にきっちりと一致する。

【００４２】

液体は、シール部材１２の底部と基板Ｗ表面間のガスシール１６によってリザーバに閉じ込められる。ガスシールは、例えば空気や合成エアーといったようなガス、しかし好ましくはN_2もしくは他の不活性ガスにより形成される。こうしたガスは、導入口１５を介してシール部材１２と基板間のギャップに加圧下で供給され、第一導出口１４により抽出される。ガス導入口１５への過圧、第一導出口１４の真空レベル、およびギャップのジオメトリは、液体を閉じ込める内部への高速の空気流が生じるように調整される。これを図３においてより詳細に示している。

【００４３】

ガスシールは２つの環状の溝１８、１９から形成されており、これらの環状の溝は、溝のまわりにスペースをとって連続した小さなコンダクト（conduct）により、それぞれ第一導入口１５と第一導出口１４に連結している。導入口１５と導出口１４は、シール部材２４の外周を囲む複数の別々のオリフィスであるか、あるいは連続した溝またはスリットである。シール部材に大きな環状のくぼみが導入口と導出口各々に設けられ、マニホールドを形成する。ガスシールはガスベアリングとして作用することにより、シール部材１２を支持することにおいても有効である。

【００４４】

ガス導入口１５の外側にあるギャップＧ１は、外側に向かう空気の流れに対して抵抗を与えるように小さく、かつ長いほうが好ましいが、必ずしもそうである必要はない。シール部材のまわりの多数の小さな穴により形成された導入口１５の半円上端のギャップＧ２は少し大きく、シール部材のまわりのガスを確実に十分に分布させる。ギャップＧ３はシールを通るガスの流れをコントロールするように選択される。ギャップＧ４は真空の分布がうまくなされるように大きくなっている。導出口１４は、導入口１５と同様の方法にて多数の小さな穴により形成されている。ギャップＧ５は、スペース内の液体にガス／酸素が拡散するのを防ぐよう、かつ、多量の液体が入って真空を妨げるのを回避するよう、かつ、毛管現象により常にこれを確実に液体で満たすよう小さくなっている。

【００４５】

このように、ガスシールは、ギャップに液体を引き込む毛管力と液体を押し出す空気流間のバランスである。ギャップがＧ５からＧ４に広くなると毛管力を減じ、空気の流れが増すことによって、液体の境界線がこの領域となり、投影システムＰＬ下で基板が動くときでさえ安定する。

【００４６】

ギャップＧ３のサイズおよびジオメトリのみならず、Ｇ２における導入口とＧ４における導出口間の圧力差がシール１６を通るガスの流量を決定し、この圧力差は具体的な実施形態に従って決定される。一方、ギャップＧ３の長さが短く、Ｇ２における絶対圧力がＧ４における絶対圧力の２倍である場合、かなりの効果が達せられる。この場合、ガス速度はガスにおける音の速度であり、これ以上は上がらない。ゆえに安定したガスの流れを達成する。

【００４７】

ガス導出系は、ガス導入圧を減じて液体をギャップＧ４に入らせて、そして真空システムによって吸い出すことにより、システムから液体を完全に取り除く際にも使用され得る。これはシールを形成するために用いられるガスと同様、液体を取扱うためにも容易に調整が可能である。ガスシールの圧力調整は、基板が動作するとき摩擦によって熱せられるギャップＧ５の液体が投影システムの下のスペースの液体温度を乱さないよう、ギャップＧ５を通る液体を確実に流動させるためにも用いられる。

【００４８】
ガス導入口および導出口のまわりのシール部材の形状は、乱流と振動を減じるべく、出来るだけ層流をもたらすように選択されるべきである。また、ガスの流れは、液体を閉じ込める最大力をもたらすべく、液体の界面における流れ方向の変化が出来るだけ大きくなるように調整されるべきである。
【００４９】
液体供給システムはリザーバ１０の液体を循環させ、それにより新鮮な液体をリザーバ１０に供給する。
【００５０】
ガスシール１６はシール部材１２を支持するのに十分な大きさの力を作り出すことが可能である。実際に、シール部材１２により支持される有効重量をあげるために、シール部材１２を基板方向にバイアスする必要がある。シール部材１２は、いずれの場合でも、投影システムに対して、かつこの下で実質的に静止位置においてＸＹ面（光軸に垂直）に保持されるが、投影システムから切り離される。シール部材１２はＺ方向、ＲｘおよびＲｙに自由に動く。
【実施例２】
【００５１】
図４および図５において第２実施例を示している。第２実施例は以下に記載の内容を除いて第１実施例と同様である。
【００５２】
この実施例において、第一ガス導出口１４に対して、ガス導入口１５の向かい側に第二ガス導出口２１６が設けられる。この方法において、装置の光軸から外側へガス導入口１５から抜け出るガスは、真空ソースに連結した第二導出口２１６により吸い上げられる。このようにして、ガスが、例えば干渉計読取り、あるいは、投影システムおよび／または基板が収容されている真空と干渉不可能であるよう、ガスシールからガスが抜け出すのを防止する。
【００５３】
２つのガス導出口を使用する本実施例の他の利点は、この設計がリソグラフィ装置において以前に用いられていたエアベアリングの設計と非常に類似することである。従って、そうしたエアベアリングから得られた経験を本実施例のガスシールに直接適用することが可能である。第２実施例のガスシールはシール手段としてだけでなくガスベアリングとしての使用に特に適することから、シール部材１２の重量の支持にこれを使用することが出来る。
【００５４】
シール部材１２の底面と基板Ｗ間の距離を測定するため、あるいは、基板Ｗの上面のトポロジーを計測するため、有効にセンサーが設けられる。ガス導入口および導出口の１４、１５、２１６に印加される圧力を変えるために調整手段を用いることが可能であり、リザーバに液体１１を閉じ込める圧力Ｐ２と、シール部材１２を支持する圧力Ｐ１およびＰ３を変える。よって、シール部材１２と基板Ｗ間の距離Ｄが変えられるか、もしくは一定の距離に維持される。同一調整手段がシール部材１２の面を維持するのに使用され得る。同一の調整手段はフィードフォワード調整ループあるいはフィードバック調整ループのいずれかにより調整され得る。
【００５５】
図５は、リザーバに液体を保持する圧力Ｐ２と、シール部材１２を支持する圧力Ｐ３を別々に調整するためにガスシールがいかに調整されうるかを詳細に示したものである。この特別な調整は、稼動中の液体損失を最小限におさえる方法を提供するため、有益である。第２実施例では、圧力Ｐ２およびＰ３を別々に調節可能にして、露光中のコンディションを変えるものである。コンディションが変わることは、異なる走査速度により、あるいは、おそらく基板Ｗのエッジがシール部材１２によってオーバーラップしていることにより、単位時間ごとの液体損失が異なるレベルとなる。これは、基板Ｗに面したシール部材

１２の面における個々の部分の基板Ｗに対する距離を変える手段を提供することにより達成される。こうした部分には、第一ガス導出口１４と、光軸に最も近いシール部材１２のエッジ間の部分２２０、ガス導入口１５と第一ガス導出口１４間の部分２３０、そして、第二ガス導出口２１６とガス導入口１５間の部分２４０を含む。これらの部分は、例えば圧電アクチュエータを使用して、基板Ｗ方向、かつ基板Ｗから離れる方向に動作される。つまり、シール部材１２の底面は圧電アクチュエータ（望ましくはスタック）から成る。該圧電アクチュエータは、これらを横切る電位差を与えることで拡張／収縮することが可能である。また他の機械的手段を用いることも可能である。

【００５６】

ガス導入口１５の下で作り出される圧力Ｐ３は、ガス導入口１５に印加されるガスの圧力Ｐ５、第一ガス導出口１４および第二ガス導出口２１６それぞれに印加されるガスの圧力Ｐ６およびＰ４、そして、基板Ｗと基板Ｗに面したシール部材１２の底面間の距離Ｄとにより決定される。また、ガス導入口とガス導出口間の水平距離も影響を与える。

【００５７】

シール部材１２の重さは圧力Ｐ３によって補正され、それによりシール部材１２はウェハＷからの距離Ｄを確定する。Ｄの減少はＰ３の増加となり、Ｄの増加はＰ３の減少となる。ゆえにこれは自己調整システムといえる。

【００５８】

圧力Ｐ３による一定の押し出し力にて、距離Ｄは、圧力Ｐ４、Ｐ５、およびＰ６によって調整のみ可能とされる。しかし、Ｐ５、Ｐ６、およびＤの組み合わせは、リザーバに液体１１を保持する圧力である圧力Ｐ２を作り出す。所定の圧力レベルで液体の容器から抜け出す液体の量は計算可能であり、液体P_{LIQ}における圧力も重要である。P_{LIQ}がＰ２よりも大きい場合、液体はリザーバから抜け出る。また、P_{LIQ}がＰ２よりも小さい場合には好ましからざる気泡が液体に発生する。液体に気泡が確実に出来ないよう、かつ、この液体の交換が必要である際にそれほど多くの液体が抜け出ることがないよう、Ｐ２をP_{LIQ}よりもわずかに小さい値に維持していくようにすることが望ましい。好ましくは、これは全て定数Ｄによりなされる。部分２２０とウェハＷ間の距離Ｄ１を変えると、抜け出る液体の量が距離Ｄ１の２乗で変化するので、リザーバから抜け出す液体の量をかなり変えることが出来る。必要とされる距離の変動はわずか１ｍｍ程度のものであり、望ましくは１０μｍである。これは、１００Ｖ以上のオーダの稼動電圧を有する圧電スタックにより容易に可能とされる。

【００５９】

あるいは、部分２３０の底部に圧電素子を配置することにより、抜け出すことの出来る液体量を調整することが可能である。距離Ｄ２を変えることは圧力Ｐ２を変えるのに有効である。しかし、この解決法は、定数Ｄを維持するために、ガス導入口１５における圧力Ｐ５の調整を必要とするであろう。

【００６０】

当然、部分２４０の低位部分と基板Ｗ間の距離Ｄ３を同様の方法で変えることも可能であり、Ｐ２およびＰ３の個々の調整に使用することも可能である。Ｐ２およびＰ３を所望の値に変えるべく、圧力Ｐ４、Ｐ５、およびＰ６と、距離Ｄ１、Ｄ２、およびＤ３を全て別個に、あるいは組み合わせて調整することが可能であることが理解されよう。

【００６１】

実際に、第２実施例は、リザーバ１０の液体量のアクティブ管理における使用に特に有効である。基板Ｗの結像が行われていない投影装置のスタンバイ状態とは、リザーバ１０の液体は空であるがそれによりシール部材１２を支持するためにガスシールはアクティブであるという状態であろう。基板Ｗが配置された後、液体がリザーバ１０内に導入される。次に基板Ｗが結像される。基板Ｗを取り除く前に、リザーバからの液体を取り除くことが出来る。最終基板の露光後にリザーバ１０内の液体が取り除かれる。液体を取り除くたびに、前に液体が満たされていた領域を乾かすようにガスパージが適用されなくてはならない。上述したように定数Ｐ３を維持しながら、液体は、Ｐ２を変えることによって第２

実施例に従って装置において容易に完全に取り除かれることが出来る。他の実施例において、Ｐ５およびＰ６（かつ必要な場合、あるいは適切である場合、Ｐ４も）を変えることにより、同様の効果を達成することが出来る。

【実施例３】

【００６２】

図６に示すように、第２実施例の代替案、あるいはさらなる展開として、第一ガス導出口１４の内側（投影システムの光軸にさらに近い）に、基板Ｗに面したシール部材１２の面にチャネル３２０が設けられる。チャネル３２０はガス導入口および導出口の１４、１５、２１６と同様の構成を有する。

【００６３】

チャネル３２０を用いることで、圧力Ｐ３とは別々に圧力Ｐ２を変えることが可能である。もしくは、リザーバ１０の液面より上方の周囲圧へチャネルを開口することにより、稼動中のリザーバからの液体消費がかなり減じられる。チャネル３２０は他のどのような実施例とも組み合わせることが可能であり、特に第１実施例と組み合わせて使用され得るが、本実施例を第２実施例との組み合わせにおいて説明した。さらなる長所は、ガス導入口１５および第一ガス導出口１４（またある特定の実施例においては第二ガス導出口２１６も）が乱されないことである。

【００６４】

さらに、ここでは３個のみの素子を示しているが、基板Ｗに面したシール部材１２の面に何個のチャネルでも取り入れることが可能である。各チャネルは、液体供給システムの剛性、液体消費、安定性、あるいは他の特性を改善するために圧力を与えられている。

【実施例４】

【００６５】

図７および図８に示した第４実施例は、以下に記載の内容を除いては第１実施例と同様である。しかし、第４実施例はここに記載のいずれか他の実施例とともに有効に使用することも可能である。

【００６６】

第４実施例において、好ましくはポーラス・カーボンや多孔質セラミック部材といった多孔質部材４１０が、ガス導入口１５に取り付けられる。ここでは、ガスはシール部材の底面から抜け出る。好ましくは、多孔質部材の底面はシール部材の底面と同一平面上にある。このポーラス・カーボン部材４１０は、（この場合基板Ｗにおける）完全に平らではない面に無関係であり、導入口１４を抜け出るガスは導入口の出口全体によく分配される。シール部材１２が基板Ｗのエッジ上に部分的に配置されるとき、このポイントにおいてガスシールが接触する面が平らでないとき、多孔質部材４１０を使用することによって得られる長所もまた明らかである。

【００６７】

第４実施例の別形態において、多孔質部材４１０を真空チャネル１４に配置することが可能である。望ましからざる圧力損失を回避しながら、多孔質部材４１０は、加圧状態を維持するように選択された孔を有するべきである。これは、基板Ｗのエッジを結像するときに有利であり、ガスベアリングは基板Ｗのエッジ上を動作する。なぜならば、たとえエッジ位置における予圧が損失するとしても、予圧の変動をかなり減じて、そして、ステージ上の浮上高と力の連続的な変化において、真空チャネルは多量かつ多種のガスにより汚染されないからである。

【実施例５】

【００６８】

上記の実施例全てにおいて一般的に、自由表面を有する、空気といったガスに露出されるリザーバ１０内に液体を有する。これは、投影システムＰＬの最終素子が、投影システムに静水力が増すことによるクラッシュの場合に破壊するのを防ぐためでる。クラッシュの間、投影システムＰＬがそれに対して作用するとき、リザーバ１０内の液体は抑制させず、液体が容易に上方にあがることを余儀なくされる。この解決法の欠点は、稼動中に自

由表面で表面波が生じ、それにより基板Ｗから投影システムＰＬに好ましからざる外乱を伝えることである。

【００６９】

この問題を解決する一つの方法は、リザーバ１０が、特にその上面が、シール部材内に完全に含まれるようにすることである。液体は第二リザーバからダクトを通してリザーバ１０に供給される。この第二リザーバは抑制されない最上面を有することができ、クラッシュの間、液体はダクトを通して第二リザーバ内に向かうことを余儀なくされることから、投影システムにおいて第一リザーバ１０に大きな静水力が生じるのを回避する。

【００７０】

こうしたクローズドシステムにおいて、投影システムにおける液体の圧力の局所的増加は、リザーバに連結するダクトが、次の等式に従う半径を有するダクトに等しい断面領域を確実に有することにより回避される。

【数３】

$$R=\left(\frac{8\Delta V\eta L}{\pi\Delta Pt}\right)^{1/4}$$

ここで、Ｒはダクト半径であり、△Ｖは時間ｔ内にリザーバ１０から取り除かれなくてはならない液体の量であり、Ｌはダクトの長さであり、ηは液体の粘度であり、そして△Ｐは第二リザーバと第一リザーバ１０間の圧力差である。基板テーブルが０．２ｍ／秒（実験により計測）の速度でクラッシュする可能性があり、かつ、ΔP_{max}は10^4 Ｐａである（最大圧力において投影システムの最終素子はダメージが生じる前は持ちこたえることが出来る）という仮定がたてられる場合、必要パイプ半径は０．２ｍのダクト長に対して約２．５ミリメータである。望ましくは、ダクトの有効半径は式から得られる最小値の少なくとも２倍である。

【００７１】

投影システムＰＬがクラッシュ時になおかつ保護されるようにしながら、リザーバ１０の液体において波の形成を回避するまた別の方法は、リザーバ１０の液体の最上面における抑制膜５１０を液体の自由表面に提供することである。この解決法は、クラッシュの場合、高すぎる圧力にせずに液体を排出させるために、安全手段５１５を必要とする。その一解決法を図９において示している。抑制膜は可とう性材料から成り、これは、液体の圧力が所定の許容最大値に達する前に液体が可とう性のある抑制膜５１０を変形させることにより、液体が、投影システムＰＬと抑制膜５１０間、もしくは抑制膜とシール部材間をそれぞれ抜け出すといった方法で、シール部材１２の壁部あるいは投影システムに取り付けされる。このように、クラッシュの場合に投影システムＰＬに損傷を与えることなく、液体が安全膜を抜け出すことが可能である。この実施例に関して、リザーバ１０の少なくとも体積の抑制膜上にスペースを有することが明らかに望ましい。よって、可とう性のある膜は、リザーバ１０における液体の最上面において波の形成を回避し得るほど十分に堅いが、一旦液体が所定の静水圧に達すると、液体が抜け出るのを防止するほどには堅くない。より堅い抑制膜との組み合わせにおいて、所定圧力以上で液体の自由な流れを可能にする圧力弁５１５を使用することで同様の効果が達せられる。

【００７２】

抑制手段のまた別の形態では、リザーバ１０の液体の最上部の自由表面に粘度の高い液体を配置する。これは、クラッシュの場合に、投影システムＰＬを妨害せず液体を抜け出させながら表面波の形成を抑制する。当然、高粘度の液体はスペース１０において使用される液体と非混和性でなくてはならない。

【００７３】

それに関する液体抑制手段５１０のさらなる代替案はメッシュで構成することである。この方法において液体の最上面は各々が小さい面積の複数部分に分割される。この複数部分の表面面積はメッシュの開口に等しく、それにより大きな表面波の生成が効果的に抑え

られるため、このようにして、共振により作り出され、かつ投影システムを阻害する大きな表面波の発生を回避する。また、メッシュによって、その開口を通る液体の流れを可能にすることで、クラッシュの際に投影システム保護する効果的な圧力解除メカニズムがもたらされる。

【実施例６】

【００７４】

図１０および図１１に示した第６実施例は、以下に記載の内容を除いて第１実施例と同様である。第６実施例は上述の実施例における提案のいくつかを使用する。

【００７５】

別の実施例において、投影システムの最終素子の下でこれを囲んで配置されたシール部材１２により、投影システムの下の領域に浸液１１が閉じ込められている。

【００７６】

シール部材１２と基板Ｗ間のガスシールは、３つのタイプの導入口および導出口から形成されている。シール部材は一般的に導出口６１４、導入口６１５、そして、さらにもう１つの導入口６１７を備えている。これらは、投影システムＰＬの最も近くに導出口６１４が、導出口６１４のすぐ外側にさらにもう１つの導入口６１７が、そして投影システムＰＬから最も遠くに導入口６１５が配置されている。導入口６１５は、環状のチャンバ６２２を介して、基板Ｗに面したシール部材１２の表面にある複数の導出ホール６２０にガス供給がなされるエアベアリングから成る。導出口６２０を抜け出す空気の力は、シール部材１２の重量の少なくとも部分を支持することと、投影システムＰＬの下の局所的な領域に閉じ込められる浸液をシールするのを助ける導出口６１４方向への空気の流れを可能にすることの両方の役割をなす。チャンバ６２２の目的は、別個のガス供給オリフィス６２５が導出ホール６２０で均一な圧力にてガスを供給するようにすることである。導出ホール６２０は直径が約０．２５ｍｍであり、約５４個の導出ホール６２０がある。導出ホール６２０とチャンバ６２２間における流量制限にあるオーダの大きさの差があり、これは、少ない数、すなわち１つだけのメイン供給オリフィス６２５であっても、導出ホール６２０全てからの均一な流出を可能にする。

【００７７】

導出ホール６２０を抜け出るガスは放射状に内側と外側の両方に流れる。導出口６１４から放射状に内側に流れる空気は、シール部材と基板Ｗ間のシールを形成するのに有効である。しかし、さらなる導入口６１７によりさらに空気の流れがもたらされる場合、シールを改善することが分かった。通路６３０はガスソース、例えば外気に連結している。導入口６１５からの空気の放射状の内側への流れは、さらなる導入口６１７から導出口６１４に向かってさらにガスを引き込むのに有効である。

【００７８】

通路６３０の端部（連続する別々の導入口ではなく）に設けられた環状の溝６３３は、溝６３３の最も内側のエッジと導出口６１４間におけるガスのシーリングフローが外周全体において確実に均一であるようにする。溝は一般に幅が２．５ｍｍであり、同様の高さを有するものである。

【００７９】

溝６３３の最も内側のエッジ６３５は図示するような半径がもたらされ、通路６３０を通って導出口６１４に向かうガスのスムーズな流れを可能にする。

【００８０】

導出口６１４はまた、高さがわずか約０．７ｍｍであるが、幅が６から７ｍｍの連続した溝６４０を有する。溝６４０の最も外側のエッジ６４２は、ほぼ９０°の鋭いエッジがもたらされ、それによってガスの流れ、特に、さらなる導入口６３０からのガスの流れはガスシールの効果を高めるように加速される。溝６４０は、環状のチャンバ６４７につながる、よって別個の導出通路６４９につながる複数の導出ホール６４５を有する。複数の導出ホール６４５は直径が約１ｍｍであり、それにより、導出ホール６４５を通過する水滴はより小さな水滴に細分される。

【００８１】
シール部材１２の液体除去効果を、さらなる導入口６１７に連結した調整弁６３８によって調整することが可能である。弁６３８はさらなる導入口６１７を通る流量の調整に有効であり、それにより、導出口６１４を通るガスシールの液体除去効果を変える。
【００８２】
シール部材の全径は１００ｍｍ程度のものである。
【００８３】
図１１は、図１０のシール部材の下側の平面図である。図から分かるように、導入口６１５は複数の別個の導入ホール６２０として提供されている。エアベアリングとしての溝が、このようなシステムにおいて変動が設定されるような能力（ガスの圧縮可能特性による）を有することから、これはメインの導入口６１５に溝を使用することに対して長所がある。小さい直径の導入ホール６２０はその中のガスは低量であるから、その能力によって生じる問題にあまり悩まされない。
【００８４】
溝６３３の形状のさらなる導入口６１７は、別個の導入ホール６２０のみを使用するときには必ずしも可能でなかった、シール部材１２の全円周において連続するガスの流れを可能にするために使用され得る。チャンバ６４７、６２２といったような有効な溝６４０を供給することにより別個の構成要素として導出口６４５を供給することは、流れを安定させるのに問題とはならない。
【００８５】
液体の導入口は図１０および図１１のシール部材１２において示されておらない。液体は、前述の実施例にて示された方法と同様の方法にて供給されるか、あるいは、いくらかの液体は、欧州特許申請番号０３２５６８２０．６号および同第０３２５６８０９．９号において記載されているように導出入される。
【実施例７】
【００８６】
第７実施例は以下に記載の内容を除いて第６実施例に類似する。図１２は、図１１と類似するシール部材１２下側の平面図である。図１２において、シール部材１２には第６実施例に示したようなさらなる導入口は設けられないが、任意に追加することも可能である。
【００８７】
第７実施例のシール部材１２は、導入ホール７２０により形成され、かつ、第６実施例の全体設計と同様のガスベアリング７１５から成る。導入口７１４は、それぞれガスソースと真空ソースに導く２つのみの通路７４５と７４７を有する環状の溝７４０から成る。この方法により通路７４５に連結したガスソースから、通路７４７に連結した真空ソースへの高速のガスの流れがもたらされる。この高速のガスの流れにより浸液をより効果的に排水することが可能となる。さらに、真空チャンバにおいてより大きく制限された真空の流れを作り出すことで、基板Ｗ上のシール部材１２の高さの変動による流れのばらつき、あるいは表面における他の漏れのもとは、ガスベアリングに対して予圧を与える真空チャンバの圧力に影響を与えない。
【実施例８】
【００８８】
第８実施例は図１４との関連において説明を行うものであり、以下に記載の内容を除いて第一実施例と同様である。
【００８９】
図１４において分かるように、第８実施例は、第一実施例と同様導入口８１５と導出口８１４を備えたシール部材１２を有する。しかし、導出口１４の下に、あるいはこれのわずかに放射状の外側に、基板Ｗの面上のガスの速度を増すガスジェットが作り出されるように配列されたさらにもう１つの導入口８１７が設けられており、それによって浸液はより効果的に基板Ｗの表面から取り除かれる。さらなる導入口８１７は、投影システムＰＬ

に放射状の内側に向かう角度で基板Ｗに向かって導かれるノズルによってもたらされる出口を有する。従い、最後の数マイクロメータの液体フィルムを水から取り除くことの出来ない、基板表面上のゼロ速度で単純な放射線状の速度分布を有する、導入口８１５と導出口８１４間の層流（レイノルズ数が約３００）が改善される。なぜならば、さらなる導入口８１７により、より高速の空気速度を有するガスが基板表面と接触するのを可能にするからである。

【００９０】

図１４から、さらなる導入口８１７のノズル出口が、導出口８１４の放射状の外側に、しかし、導入口８１５よりも導出口８１４の近くに設けられていることが分かる。

【実施例９】

【００９１】

第９実施例を図１５および図１６に示しており、これは以下に記載の内容を除いて第一実施例と同様である。

【００９２】

第９実施例において、基板Ｗに面するシール部材の底面における導出口９１４の口が、導出口９１４内への空気の速度を増すように修正されている。これは、導出口９１４の通路を同じサイズに保ちながら、導入口９１４の口のサイズを減じることで達せられる。これは、シール部材１２の材料を通路の中央に向かって伸長して、外側への追加部材９４０と内側への追加部材９５０を形成することにより、より小さい口を設けることで達成される。外側への追加部材９４０は内側への追加部材９５０よりも小さく、これら２つの部材９４０、９５０間のギャップは、導出口９１４の残り部分よりも約２０倍小さい。口の幅は約１００から３００μｍである。

【００９３】

図１６において、第９実施例のさらなる別の形態を示しており、ここでは、第８実施例における導入口８１７に類似するさらなる導入口９１７が設けられている。しかし、この場合、さらなる導入口９１７は基板Ｗの面にほぼ平行な噴流をもたらし、それにより導出口９１４の口に入るガスが加速される。

【実施例１０】

【００９４】

第１０実施例を図１７に示しており、本実施例は以下に記載の内容を除いて第１実施例と同様である。

【００９５】

第１０実施例において、第８実施例と同様の原理に従って基板Ｗの表面上のガス速度を増すことによって液体除去効率が改善される。導入口１０１５から出て、導出口１０１４に向かって放射状の内側に動くガスは、環状の溝１０１８の下を通過する。図示するように、溝の効果は、ガスがその放射状の最も外側にある溝に入り、放射状の内側面において基板Ｗの方向に角度を持って出ることである。従い、導出口１０１４への入り口で基板Ｗの表面上のガスの速度は増し、液体除去効率が改善される。

【００９６】

どの実施例のフューチャであっても、他の実施例のいくつかの、あるいは全部のフューチャとともに使用可能であることは明らかである。

【００９７】

以上、本発明の実施形態を詳細に説明したが、本発明の範囲を逸脱することなく他の方法でも具体化できることは当業者にとって明らかである。本詳細説明は本発明を制限する意図ではない。

【図面の簡単な説明】

【００９８】

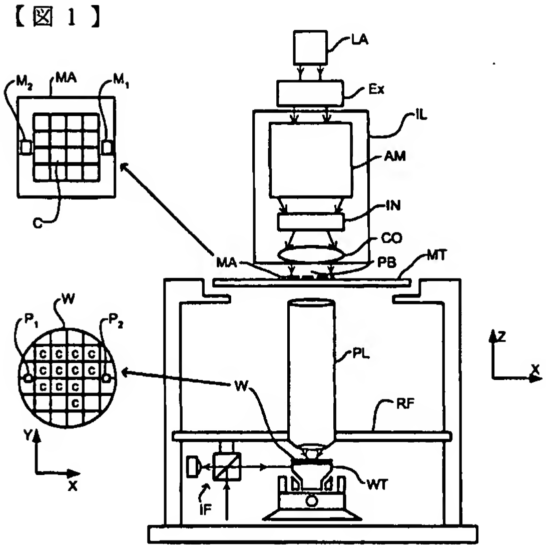
【図１】本発明の実施例におけるリソグラフィ投影装置を示したものである。

【図２】本発明の第１実施例の液体リザーバを示したものである。

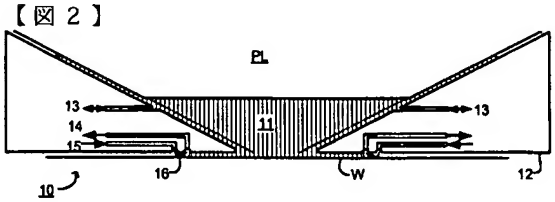
【図３】本発明の第１実施例の液体リザーバの部分の拡大図である。

【図４】本発明の第２実施例の液体リザーバを示したものである。
【図５】本発明の第２実施例の液体リザーバの部分の拡大図である。
【図６】本発明の第３実施例の液体リザーバの拡大図である。
【図７】本発明の第４実施例の液体リザーバを示したものである。
【図８】本発明の第４実施例の液体リザーバの部分の拡大図である。
【図９】本発明の第５実施例の液体リザーバを示したものである。
【図１０】本発明の第６実施例の液体リザーバを示したものである。
【図１１】第６実施例のシール部材の下側の平面図である。
【図１２】第７実施例のシール部材の下側の平面図である。
【図１３】第７実施例の液体リザーバの断面図である。
【図１４】第８実施例の液体リザーバの断面図である。
【図１５】第９実施例の液体リザーバの断面図である。
【図１６】また別の第９実施例の変形態様の液体リザーバの断面図である。
【図１７】第１０実施例の液体リザーバの断面図である。

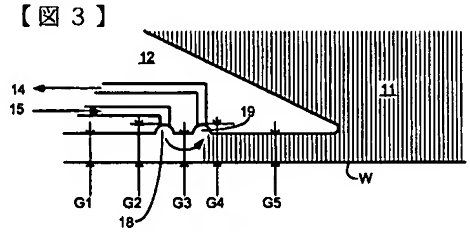
【図１】



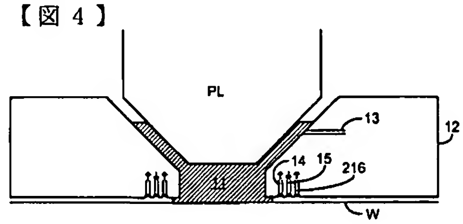
【図２】



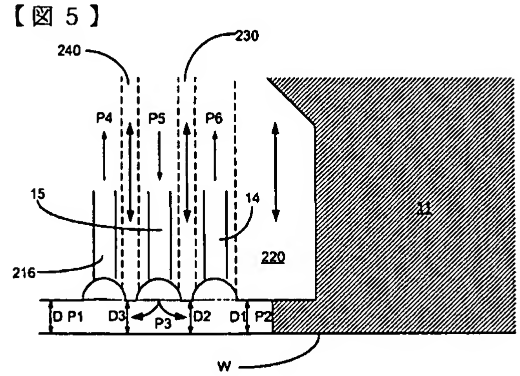
【図３】



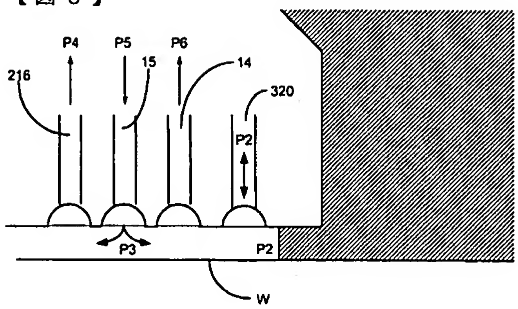
【図４】



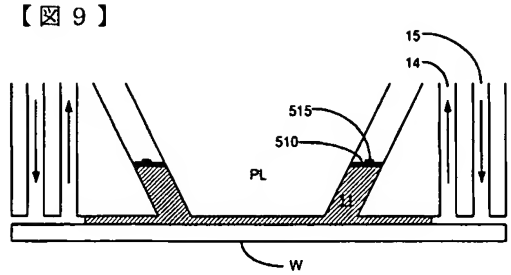
【図５】



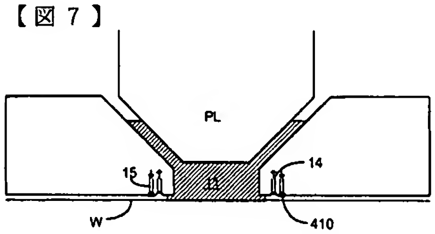
【図６】



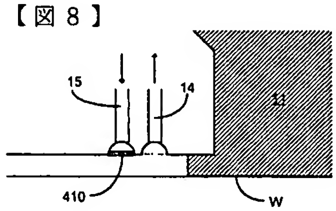
【図９】



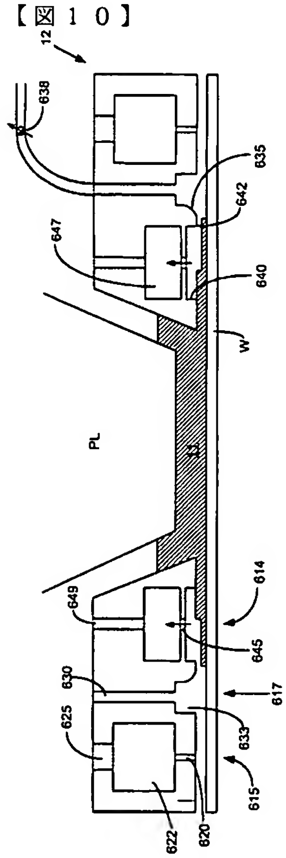
【図７】



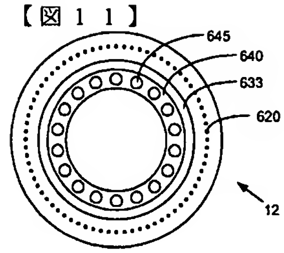
【図８】



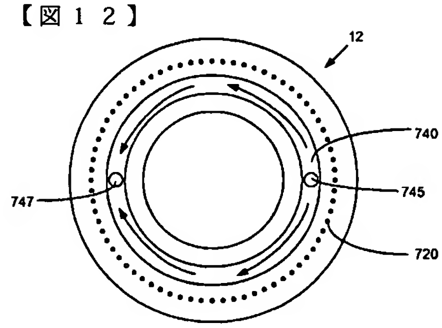
【図１０】



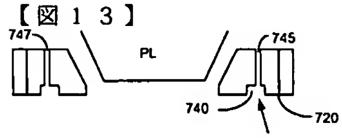
【図１１】



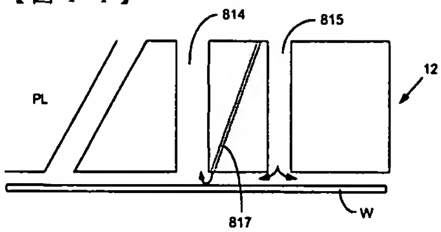
【図１２】



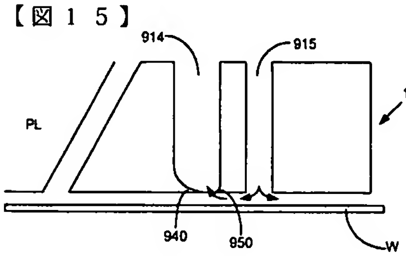
【図１３】



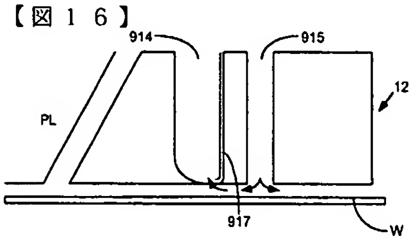
【図１４】



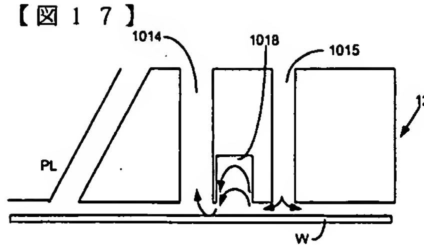
【図１５】



【図１６】



【図１７】



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Ｆターム(参考) 5F046 BA03 CB24 DA27 DC10

【外国語明細書】

Lithographic Apparatus and Device Manufacturing Method

The present invention relates to a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate; and
- a liquid supply system for at least partly filling a space between the final element of said projection system and said substrate with a liquid.

The term "patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such patterning means include:

- A mask. The concept of a mask is well known in lithography, and it incldes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.
- A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed

areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning means can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

- A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (*e.g.* comprising one or more dies) on a substrate (e.g. silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the

projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus —commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or antiparallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, thesubstrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any

of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, incorporated herein by reference.

It has been proposed to immerse the substrate in a lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the final element of the projection system and the substrate. The point of this is to enable imaging of smaller features since the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as increasing the effective NA of the system.)

However, submersing the substrate table in liquid means that there is a large body of liquid that must be accelerated during a scanning exposure. This requires additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

There are several difficulties associated with having liquids in a lithographic projection apparatus. For example, escaping liquid can cause a problem by interfering with interferometers and, if the lithographic projection apparatus requires the beam to be held in a vacuum, by destroying the vacuum. Furthermore, the liquid can be used up at a high rate unless suitable precautions are taken.

Further problems associated with immersion lithography include the difficulty in keeping the depth of the liquid constant and transfer of substrates to and from the imaging position i.e. under the final projection system element. Also, contamination of the liquid (by chemicals dissolving in it) and increase in temperature of the liquid deleteriously affect the imaging quality achievable.

In the event of a computer failure or power failure or loss of control of the apparatus for any reason, steps need to be taken to protect, in particular, the optical elements of the projection system. It may be necessary to take steps to avoid spillage of the liquid over other components of the apparatus.

If a liquid supply system is used in which the liquid has a free surface, steps need to

be taken to avoid the development of waves in that free surface due to forces applied to the liquid supply system. Waves can transfer vibrations to the projection system from the moving substrate.

WO 99/49504 discloses a lithographic apparatus in which a liquid is supplied to the space between the projection lens and the wafer. As the wafer is scanned beneath the lens in a –X direction, liquid is supplied at the +X side of the lens and taken up at the–X side.

It is an object of the present invention to provide a lithographic projection apparatus in which a space between the substrate and projection system is filled with a liquid whilst minimizing the volume of liquid that must be accelerated during stage movements.

This and other objects are achieved according to the invention in a lithographic apparatus as specified in the opening paragraph, characterized in that said liquid supply system comprises:

- a seal member extending along at least a part of the boundary of said space between the final element of said projection system and said substrate table; and
- a gas seal means for forming a gas seal between said seal member and the surface of said substrate.

The gas seal means thus forms a non-contact seal between the seal member and the substrate so that the liquid is contained in the space between the final element of the projection system and the substrate, even as the substrate moves under the projection system, e.g. during a scanning exposure.

The seal member may be provided in the form of a closed loop, whether circular, rectangular, or other shape, around the space or may be incomplete, *e.g.* forming a U-shape or even just extending along one side of the space. If the seal member is incomplete, it should be positioned to confine the liquid as the substrate is scanned under the projection system.

Preferably, the gas seal means is a gas bearing for supporting said seal member. This has the advantage that the same part of the liquid supply system can be used both for bearing and for sealing the liquid in a space between the final element of the projection system and the substrate, thereby reducing the complexity and weight of the seal member. Also, previous experience gained in the use of gas bearings in vacuum environments can be

called on.

Preferably, the gas seal means comprises a gas inlet and a first gas outlet formed in a face of said seal member that opposes said substrate, means for supplying gas under pressure to said gas inlet and vacuum means for extracting gas from said first gas outlet. More preferably, the gas inlet is located further outward from the optical axis of said projection system than said first gas outlet. In this way, the gas flow in the gas seal is inward and most efficiently contains the liquid. In this case, the gas seal means advantageously further comprises a second gas outlet formed in the face of the sealmember which opposes the substrate, the first and second gas outlets being formed on opposite sides of the gas inlet. The second gas outlet ensures minimal escape of gas from the gas inlet into the environment surrounding the seal member. Thus, the risk of gas escaping and interfering with the interferometers or degrading a vacuum in the lithographicapparatus, is minimized.

The liquid supply system may also comprise sensors for measuring the distance between the face of the seal member and the substrate and/or the topography of the top surface of the substrate. In this way, control means can be used to vary the distance between the face of the seal member and the substrate by controlling, for example, the gas seal means either in a feed-forward or a feed-back manner.

The apparatus may further comprise means for varyirg the level of a portion of said face of said seal member between the first gas outlet and an edge of the face nearest the optical axis relative to the remainder of the face. This allows the pressure containing the liquid in the space, to be controlled independently of the pressure below the inlet so that the height of the seal member over the substrate can be adjusted without upsetting the balance of forces holding the liquid in the space. An alternative way of ensuring this is to use a means for varying the level of a portion of the face between the first or second gas outlets and the gas inlet relative to the remainder of the face. Those three systems may be used in any combination.

An alternative way of separating a sealing function and bearing funcion of the gas seal means is to provide a channel formed in the face of the seal member located nearer to the optical axis of the projection system than the first gas outlet. The pressure in that channel can be varied to contain the liquid in the space whereas the gas in and out-lets may be used to vary the height of the seal member above the substrate so that they only operate to support the seal member and have little, if any, sealing function.

A further advantageous feature is for a porous member to be disposed over the gas inlet for evenly distributing gas flow over the area of the gas inlet.

It is convenient to form the gas in and out-lets so that each comprises a groove in said face of said seal member opposing said substrate and a plurality of conduits leading into said groove at spaced locations.

It is also preferred that the gap between said seal member and the surface of said substrate inwardly of said gas seal means is small so that capillary action draws liquid into the gap and/or gas from the gas seal means is prevented from entering the space. The balance between the capillary forces drawing liquid under the seal member and the gas flow pushing it out forms a particularly stable seal.

It is a further object of the present invention to provide a lithographic projection apparatus in which a space between the substrate and the projection system is filled with a liquid whilst minimizing the transmission of disturbance forces between the substrate and projection system.

This and other objects are achieved according to the invention in a lithographic apparatus as specified in the opening paragraph, characterized in that said space is in liquid connection with a liquid reservoir through a duct and the minimum cross sectional area of said duct in a plane perpendicular to the direction of fluid flow is at least $\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$, where ΔV is the volume of liquid which has to be removed from said space within time t_{min}, L is the length of the duct, η is viscosity of liquid in said space and ΔP_{max} is the maximum allowable pressure on said final element.

This apparatus has the advantage that the liquid can be completely constrained such that it does not have a large free surface for the development of waves i.e. the space or reservoir is enclosed at the top and the reservoir is full of liquid. This is because the amount of fluid which can flow through the duct in a given time (time of crash measured experimentally) is large enough to avoid damage to the final element of the projection system when the apparatus crashes because the liquid can escape through the duct before pressure in the space build up to levels at which damage can occur. The liquid must escape when the seal member moves relative to the final element otherwise the hydrostatic pressure applied to the final element during relative movement of the final element to the seal

member can damage the final element.

In another aspect of the invention, there is provided a lithographic apparatus as specified in the opening paragraph, characterized in that the liquid supply system further comprises, on a top surface of liquid in said liquid supply system, a suppression means for suppressing development of waves and including pressure release means.

In this way, the development of waves can be suppressed by contact of the suppression means with a top surface of the liquid. However the liquid still can escape from the space in the event of a crash to avoid damaging the final element.

One way of providing the suppression means is through a flexible membrane or alternatively placing a high viscosityliquid which is immiscible with the liquid in the space on the top surface of the liquid in the space. In each of these cases the pressure release functionality is provided by the flexibility of the suppression means.

Another aspect of the invention provides a device manufacturing method comprising the steps of:

- providing a substrate that is at least partially covered by a layer of radiation sensitive material;
- providing a projection beam of radiation using a radiation system;
- using patterning means to endow the projection beam with a pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material; and
- providing a liquid to fill a space between the substrate and a final element of a projection system used in said step of projecting;

either characterized by:

- forming a gas seal between a seal member extending along at least a part of the boundary of said space and the surface of said substrate;

or

- providing a liquid reservoir in liquid connection with said space through a duct

and

- ensuring that said duct has a minimum cross-sectional area in a plane perpendicular to the direction of flow of liquid of $\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$, where

ΔV is the volume of liquid which has to be removed from said space within time t_{min}, L is the length of the duct, η is viscosity of liquid in said space and ΔP_{max} is the maximum allowable pressure on said final element;

or characterized by:

- suppressing development of waves on said liquid with a suppression means and allowing for release of pressure of said liquid.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms "radiation" and "beam" are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (*e.g.* with a wavelength of 365, 248, 193, 157 or 126 nm).

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings, in which:

Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

Figure 2 depicts the liquid reservoir of the first embodiment of the invention;

Figure 3 is an enlarged view of part of the liquid reservoir of the first embodiment of the invention;

Figure 4 depicts the liquid reservoir of the second embodiment of the invention;

Figure 5 is an enlarged view of part of the liquid reservoir of the second embodiment of the invention;

Figure 6 is an enlarged view of the liquid reservoir of the third embodiment of the present invention;

Figure 7 depicts the liquid reservoir of the fourth embodiment of the present invention;

Figure 8 is an enlarged view of part of the reservoir of the fourth embodiment of the present invention;

Figure 9 depicts the liquid reservoir of a fifth embodiment of the present invention

Figure 10 depicts the liquid reservoir of a sixth embodiment of the present invention;

Figure 11 depicts, in plan, the underside of the seal member of the sixth embodiment;

Figure 12 depicts, in plan, the underside of the seal member of the seventh embodiment;

Figure 13 depicts, in cross section, the liquid reservoir of the seventh embodiment

Figure 14 depicts, in cross section, the liquid reservoir of an eighth embodiment

Figure 15 depicts, in cross section, the liquid reservoir of a ninth embodiment

Figure 16 depicts, in cross section, the liquid reservoir of an alternative ninth embodiment; and

Figure 17 depicts, in cross section, the liquid reservoir of a tenth embodiment.

In the Figures, corresponding reference symbols indicate corresponding parts.

Embodiment 1

Figure 1 schematicallydepicts a lithographic projection apparatus according to a particular embodiment of the invention. The apparatus comprises:

- a radiation system Ex, IL, for supplying a projection beam PB of radiation (*e.g.* DUV radiation), which in this particular case also comprises a radiation source LA;
- a first object table (mask table) MT provided with a mask holder for holding a mask MA (*e.g.* a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;
- a projection system ("lens") PL (*e.g.* a refractive lens system) for imaging an irradiated portion of the mask MA onto a target portion C (*e.g.* comprising one or more dies) of the substrate W.

As here depicted, the apparatus is of a transmissive type (*e.g.* has a transmissive mask).

However, in general, it may also be of a reflective type, for example ¢.g. with a reflective mask). Alternatively, the apparatus may employ another kind of patterning means, such as a programmable mirror array of a type as referred to above.

The source LA (*e.g.* an excimer laser) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expanderEx, for example. The illuminator IL may comprise adjusting meansAM for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its crosssection.

It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and Claims encompass both of these scenarios.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, *e.g.* after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

The depicted apparatus can be used in two different modes:

- In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (*i.e.* a single "flash") onto a target portion C. The

substrate table WT is then shifted in the x and/or y directions so thata different target portion C can be irradiated by the beam PB;

- In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or 1/5). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

Figure 2 shows the liquid reservoir 10 between the projection system and the substrate stage. The liquid reservoir 10 is filled with a liquid 11 having a relatively high refractive index, e.g. water, provided via inlet/outlet ducts 13. The liquid has the effect that the radiation of the projection beam has a shorter wavelength in the liquid than in air or a vacuum, allowing smaller features to be resolved. It is well known that the resolution limit of a projection system is determined, *inter alia*, by the wavelength of the projection beam and the numerical aperture of the system. The presence of the liquid may also be regarded as increasing the effective numerical aperture. Furthermore, at fixed numerical aperture, the liquid is effective to increase the depth of field.

The reservoir 10 forms a contactless seal to the substrate around the image field of the projection system so that liquid is confined to fill a space between the substrate surface and the final element of the projection system. The reservoir is formed by a seal member 12 positioned below and surrounding the final element of the projection system PL. Liquid is brought into the space below the projection system and within the seal member 12. The seal member 12 extends a little above the final element of the projection system and the liquid level rises above the final element so that a buffer of liquid is provided. The seal member 12 has an inner periphery that at the upper end preferably closely conforms to the step of the projection system or the final element thereof and may, e.g., be round. At the bottom, the inner periphery closely conforms to the shape of the image field, e.g., rectangular though this need not be the case.

The liquid is confined in the reservoir by a gas seal 16 between the bottom of the seal member 12 and the surface of the substrate W. The gas seal is formed by gas, e.g. air or synthetic air but preferably N_2 or another inert gas, provided under pressure via inlet 15

to the gap between seal member 12 and substrate and extracted via first outlet 14. The overpressure on the gas inlet 15, vacuum level on the first outlet 14 and geometry of the gap are arranged so that there is a high-velocity air flow inwards that confines the liquid. This is shown in more detail in Figure 3.

The gas seal is formed by two annular grooves 18, 19 which are connected to the first inlet 15 and first outlet 14 respectively by a series of small conducts spaced around the grooves. The in-and out-lets 14, 15 may either be a plurality of discrete orifices around the circumference of the seal member 24 or may be continuous grooves or slits. A large annular hollow in the seal member may be provided in each of the inlet and outlet to form a manifold. The gas seal may also be effective to support the seal member 12 by behaving as a gas bearing.

Gap G1, on the outer side of the gas inlet 15, is preferably small and long so as to provide resistance to air flow outwards but need not be. Gap G2, at the radius of the inlet 15, is a little larger to ensure a sufficient distribution of gas around the seal member, the inlet 15 being formed by a number of small holes around the seal member. Gap G3 is chosen to control the gas flow through the seal. Gap G4 is larger to provide a good distribution of vacuum, the outlet 14 being formed of a number of small holes in the same manner as the inlet 15. Gap G5 is small to prevent gas/oxygen diffusion into the liquid in the space, to prevent a large volume of liquid entering and disturbing the vacuum and to ensure that capillary action will always fill it with liquid.

The gas seal is thus a balance between the capillary forces pulling liquid into the gap and the airflow pushing liquid out. As the gap widens from G5 to G4, the capillary forces decrease and the airflow increases so that the liquid boundary will lie in this region and be stable even as the substrate moves under the projection system PL.

The pressure difference between the inlet, at G2 and the outlet at G4 as well as the size and geometry of gap G3, determine the gas flow through the seal 16 and will be determined according to the specific embodiment. However, a possible advantage is achieved if the length of gap G3 is short and absolute pressure at G2 is twice that at G4, in which case the gas velocity will be the speed of sound in the gas and cannot rise any higher. A stable gas flow will therefore be achieved.

The gas outlet system can also be used to completely remove the liquid from the system by reducing the gas inlet pressure and allowing the liquid to enter gap G4 and be sucked out by the vacuum system, which can easily be arranged to handle the liquid, as well

as the gas used to form the seal. Control of the pressure in the gas seal can also be used to ensure a flow of liquid through gap G5 so that liquid in this gap that is heated by friction as the substrate moves does not disturb the temperature of the liquid in the space below the projection system.

The shape of the seal member around the gas inlet and outlet should be chosen to provide laminar flow as far as possible so as to reduce turbulence and vibration. Also, the gas flow should be arranged so that the change in flow direction at the liquid interface is as large as possible to provide maximum force confining the liquid.

The liquid supply system circulates liquid in the reservoir 10 so that fresh liquid is provided to the reservoir 10.

The gas seal 16 can produce a force large enough to support the seal member 12. Indeed, it may be necessary to bias the seal member 12 towards the substrate to make the effective weight supported by the seal member 12 higher. The seal member 12 will in any case be held in the XY plane (perpendicular to the optical axis) in a substantially stationary position relative to and under the projection system but decoupled from the projection system. The seal member 12 is free to move in the Z direction and Rx andRy.

Embodiment 2

The second embodiment is illustrated in Figures 4 and 5 and is the same as the first embodiment except as described below.

In this embodiment a second gas outlet 216 is provided on the opposite side of the gas inlet 15 to the first gas outlet 14. In this way any gas escaping from the gas inlet 15 outwards away from the optical axis of the apparatus is sucked up by second gas outlet216 which is connected to a vacuum source. In this way gas is prevented from escaping from the gas seal so that it cannot interfere, for example, with interferometer readings or with a vacuum in which the projection system and/or substrate are housed.

Another advantage of using the two gas outlet embodiment is that the design is very similar to that of air bearings previously used in lithographic projection apparatus. Thus the experience gained with those air bearings can be applied directly to the gas seal of this embodiment. The gas seal of the second embodiment is particularly suitable for use as

gas bearing, as well as a seal means, such that it can be used to support the weight of the seal member 12.

Advantageously sensors may be provided to either measure the distance between the bottom face of the seal member 12 and the substrate W or the topography of the top surface of the substrate W. A control means may then be used to vary the pressures applied to the gas in- and out-lets 14, 15, 216 to vary the pressure P2 which constrains the liquid 11 in the reservoir and the pressures P1 and P3 which support the seal member 12. Thus the distance D between the seal member 12 and the substrate W may be varied or kept at a constant distance. The same control means may be used to keep the seal member 12level. The control means may be controlled either by a feed forward or a feedback control loop.

Figure 5 shows in detail how the gas seal can be regulated to control independently the pressure P2 holding the liquid 11 in the reservoir andP3 which supports the seal member 12. This extra control is advantageous because it provides a way of minimizing liquid losses during operation. The second embodiment allows pressures P2 and P3 to be controlled independently to account for varying conditions during exposure. Varying conditions might be different levels of liquid loss per unit time because of different scanning speeds or perhaps because the edge of a substrate W is being overlapped by the seal member 12. This is achieved by providing means for varying the distance to the substrate W of discrete portions of the face of the seal member 12 facing the substrate W. These portions include the portion 220 between the first gas outlet 14 and the edge of the seal member 12 nearest the optical axis, the portion 230 between the gas inlet 15 and the first gas outlet 14 and the portion 240 between the second gas outlet 216 and the gas inlet 15. These portions may be moved towards and away from the substrate W by the use of piezoelectric actuators for example. That is the bottom face of the seal member 12 may comprise piezoelectric actuators (preferably stacks) which can be expanded/contracted by the application of a potential difference across them. Other mechanical means could also be used.

The pressure P3 which is created below the gas inlet 15 is determined by the pressure of gas P5 applied to the gas inlet 15, pressures of gas P6 and P4 applied to the first and second gas outlets 14 and 216 respectively and by the distance D between the substrate W and the bottom face of the seal member 12 facing the substrate W. Also the horizontal distance between the gas in and out-lets has an effect.

The weight of the seal member 12 is compensated for by the pressure of P3 so that

the seal member 12 settles a distance D from the wafer W. A decrease in D leads to an increase in P3 and an increase in D will lead to a decrease in P3. Therefore this is aself regulating system.

Distance D, at a constant pushing force due to pressure P3, can only be regulated by pressures P4, P5 and P6. However, the combination of P5, P6 and D creates pressure P2 which is the pressure keeping the liquid 11 in the reservoir. The amount of liquid escaping from a liquid container at given levels of pressure can be calculated and the pressure in the liquid P_{LIQ} is also important. If P_{LIQ} is larger than P2, the liquid escapes from the reservoir and if P_{LIQ} is less than P2, air bubbles will occur in theliquid which is undesirable. It is desirable to try to maintain P2 at a value slightly less than P_{LIQ} to ensure that no bubbles form in the liquid but also to ensure that not too much liquidescapes as this liquid needs to be replaced. Preferably this can all be done with a constant D. If the distance D1 between portion 220 and the wafer W is varied, the amount of liquid escaping from the reservoir can be varied considerably as the amount of liquid escaping varies as a square of distance D1. The variation in distance required is only of the order of 1mm, preferably 10 μm and this can easily be provided by a piezoelectric stack with an operational voltage of the order of 100V or more.

Alternatively, the amount ofliquid which can escape can be regulated by placing a piezoelectric element at the bottom of portion 230. Changing the distance D2 is effective to change pressure P2. However, this solution might require adjustment of pressure P5 in gas inlet 15 in order to keep D constant.

Of course the distance D3 between the lower part of portion 240 and substrate W can also be varied in a similar way and can be used to regulate independently P2 and P3. It will be appreciated that pressures P4, P5 and P6 and distances D1, D2 and D3 can all be regulated independently or in combination to achieve the desired variation of P2 and P3.

Indeed the second embodiment is particularly effective for use in active management of the quantity of liquid in the reservoir 10. The standby situation of the projection apparatus could be, where no substrate W is being imaged, that the reservoir 10 is empty of liquid but that the gas seal is active thereby to support the seal member 12. After the substrate W has been positioned, liquid is introduced into the reservoir 10. The substrate W is then imaged. Before the substrate W is removed the liquid from the reservoir can be removed. After exposure of the last substrate the liquid in the reservoir 10 will be removed. Whenever liquid is removed, a gas purge has to be applied to dry the area

previously occupied by liquid. The liquid can obviously be removed easily in the apparatus according to the second embodiment by variation of P2 whilst maintaining P3 constant as described above. In other embodiments a similar effect can be achieved by varying P5 and P6 (and P4 if necessary or applicable).

Embodiment 3

As an alternative or a further development of the second embodiment as shown in Figure 6, a channel 320 may be provided in the face of the seal member 12 facing the substrate W inwardly (i.e. nearer to the optical axis of the projection system) of the first gas outlet 14. The channel 320 may have the same construction as the gas in- and out-lets 14, 15, 216.

Using the channel 320pressure P2 may be varied independently of pressure P3. Alternatively, by opening this channel to environmental pressure above the liquid level in the reservoir 10, the consumption of liquid from the reservoir during operation is greatly reduced. This embodiment has been illustrated in combination with the second embodiment though the channel 320 may be used in combination with any of the other embodiments, in particular the first embodiment. A further advantage is that the gas inlet 15 and first gas outlet 14 (and for certain embodiments second gas outlet 216) are not disturbed.

Furthermore, although only three elements have been illustrated any number of channels may be incorporated into the face of the seal member 12 facing the substrate W, each channel being at a pressure to improve stiffness, liquid consumption, stability or other property of the liquid supply system.

Embodiment 4

The fourth embodiment which is illustrated in Figures 7 and 8 is the same as the first embodiment except as described below. However, the fourth embodiment may also be advantageously used with any of the other embodiments described.

In the fourth embodiment a porous member 410, preferably porous carbon or a porous ceramic member, is attached to the gas inlet 15 where gas exits the bottom face of the seal member 12. Preferably the bottom of the porous member is co-planar with the bottom of the seal member. This porous carbon member 410 is insensitive to surfaces which are not completely flat (in this case substrate W) and the gas exiting the inlet 14 is well distributed over the entire exit of the inlet. The advantage gained by using the porous member 410 is also apparent when the seal member 12 is positioned partly over the edge of the substrate W as at this point the surface which the gas seal encounters is uneven.

In a variant of the fourth embodiment, the porous member 410 can be placed in the vacuum channel(s) 14. The porous member 410 should have a porosity chosen to maintain under pressure whilst preventing unacceptable pressure loss. This is advantageous when imaging the edge of the substrate W and the gas bearing moves over the edge of the substrate W be cause although the preload force at the position of the edge might be lost, the vacuum channel is not contaminated with a large and variable amount of gas, greatly reducing variations in the preload and as a consequence variation in flying height and forces on the stage.

Embodiment 5

All of the above described embodiments typically have liquid in the reservoir 10 exposed to a gas, such as air, with a free surface. This is to prevent the final element of the projection system PL from breaking in a case of a crash due to build up of hydrostatic forces on the projection system. During a crash the liquid in the reservoir 10 is unconstrained such that the liquid will easily give *i.e.* be forced upwards, when the projection system PL moves against it. The disadvantage of this solution is that surface waves may occur on the free surface during operation thereby transmitting disturbance forces from the substrate W to the projection system PL, which is undesirable.

One way of solving this problem is to ensue that the reservoir 10 is completely contained within a seal member, particularly the upper surface. Liquid is then fed to the reservoir 10 through a duct from a secondary reservoir. That secondary reservoir can have an unconstrained top surface and during a crash liquid is forced through the duct into the

second reservoir such that the build up of large hydrostatic forces in the first reservoir 10 on the projection system can be avoided.

In such a closed system the local build up of pressure in the liqpid on the projection system is avoided by ensuring that the duct connecting the reservoirs has a cross-sectional area equivalent to a duct with a radius according to the following equation

$$R = \left(\frac{8\Delta V\eta L}{\pi\Delta Pt}\right)^{1/4}$$

where R is the duct radius, ΔV is the volume of liquid which has to be removed from the reservoir 10 within time t, L is the length of the duct, η is viscosity of the liquid and ΔP is the pressure difference between the secondary reservoir and the primary reservoir 10. If an assumption is made that the substrate table can crash with a speed of 0.2 m/sec (measured by experiment) and ΔP_{max} is 10^4 Pa (about the maximum pressure the final element of the project system can withstand before damage results), the required pipe radius is about 2.5 millimeters for a duct length of 0.2 m. Preferably the effective radius of the duct is at least twice the minimum given by the formula.

An alternative way to avoid the buildup of waves in the liquid in the reservoir whilst still ensuring that the projection system PL is protected in acrash, is to provide the free surface of the liquid with a suppression membrane 510 on the top surface of the liquid in the reservoir 10. This solution requires a safety means 515 to allow the liquid to escape in the case of a crash without the build-up of too high a pressure. One solution is illustrated in Figure 9. The suppression membrane may be made of a flexible material which is attached to the wall of the seal member 12 or the projection system in such a way that before the pressure in the liquid reaches a predetermined allowed maximum, liquid is allowed to deform the flexible suppression membrane 510 such that liquid can escape between the projection system PL and the suppression membrane 510 or between the suppression membrane and the seal member, respectively. Thus in a crash it is possible for liquid to escape above the safety membrane without damaging with projection system PL. For this embodiment it is obviously preferable to have a space above the suppression membrane of at least the volume of a reservoir 10. Thus the flexible membrane is stiff enough to prevent the formation of waves in the top surface of the liquid in the reservoir 10 but is not stiff enough to prevent liquid escaping once the liquid reaches a predetermined hydrostatic pressure. The same effect can be achieved by use of pressure valves 515 which allow the free-flow of liquid above a predetermined pressure in combination with a stiffer

suppression membrane.

An alternative form of suppression means is to place a high viscosity liquid on the top free surface of the liquid in the reservoir 10. This would suppress surface wave formation whilst allowing liquid to escape out of the way of the projection system PL in the case of a crash. Obviously the high viscosity liquid must be immiscible with the liquid used in the space 10.

A further alternative for the liquid suppression means 510 is for it to comprise a mesh. In this way the top surface of the liquid can be split into several parts each of smaller area. In this way, development of large surfacewaves which build up due to resonance and disturb the projection system is avoided because the surface area of the several parts is equal to the mesh opening so that the generation of large surface waves is effectively damped. Also, as the mesh allows flow of liquid through its openings, an effective pressure release mechanism is provided for the protection of the projection system in the case of a crash.

Embodiment 6

The sixth embodiment as illustrated in Figures 10 and 11 is the same as the first embodiment except as described below. The sixth embodiment uses several of the ideas in the foregoing embodiments.

As with the other embodiments, the immersion liquid 11 is confined to an aea under the projection system PL by a seal member 12 positioned below and surrounding the final element of a projection system.

The gas seal between the seal member 12 andthe substrate W is formed by three types of in-and-out-let. The seal member is generally made up of an outlet 614, an inlet 615 and a further inlet 617. These are positioned with the outlet 614 nearest the projection system PL, readily outwardly of the outlet 614 the further inlet 617 and furthest from the projection system PL the inlet 615. The inlet 615 comprises the air bearing in which gas is provided to a plurality of outlet holes 620 in the surface of the seal member 12 facing the substrate W via an annular chamber 622. The force of the air exiting the outlet 620 both supports at least part of the weight of the seal member 12 and well as providing a flow of

air towards the outlet 614 which helps seal the immersion liquid to be confined to a local area under the projection system PL. The purpose of the chamber 622 is so that the discrete gas supply orifice(s) 625 provide gas at a uniform pressure at the outlet holes 620. The outlet holes 620 are about 0.25 mm in diameter and there are approximately 54 outlet holes 620. There is an order of magnitude difference in flow restriction between the outlet holes 620 and the chamber 622 which ensures an even flow out ofall of the outlet holes 620 despite the provision of only a small number or even only one main supply orifice 625.

The gas exiting the outlet holes 620 flows bothradially inwardly and outwardly. The air flowingradially inwardly up the outlet 614 is effective to form a seal between the seal member 12 and the substrate W. However, it has been found that the seal is improved if a further flow of air is provided by a further inlet 617. Passage 630 is connected to a gas source, for example the atmosphere. The flow of airradially inwardly from the inlet 615 is effective to draw further gas from the further inlet 617 towards the outlet 614.

An annular groove 633 which is provided at the end of the passage 630 (rather than a series of discrete inlets) ensures that the sealing flow of gas between theinner most edge of the groove 633 and the outlet 614 is even around the whole circumference. The groove is typically 2.5 mm wide andof a similar height.

The inner most edge 635 of the groove 633 is, as illustrated, provided with a radius to ensure smooth flow of the gas through passage 630 towards the outlet 614.

The outlet 614 also has a continuous groove 640 which is approximately only 0.7 mm high but 6 to 7 mm wide. The outer most edge 642 of the groove 640 is provided as a sharp, substantially 90°, edge so that the flow of gas, in particular the flow of gas out of further inlet 630 is accelerated to enhance the effectiveness of the gas seal. The groove 640 has a plurality of outlet holes645 which lead into an annular chamber 647 and thus to discrete outlet passage 649. The plurality of outlet holes 645 are approximately 1mm in diameter such that water droplets passing through the outlet holes 645 are broken up into smaller droplets.

The effectiveness of liquid removal of the seal member 12 can be adjusted by an adjustable valve 638 connected to the further inlet 617. The valve 638 is effective to adjust the flow through further inlet 617 thereby to vary the effectiveness of liquid removal of the gas seal 12 through outlet 614.

The overall diameter of the seal member is of the order of 100 mm.

Figure 11 shows, in plan, the underside of the seal member 12 of Figure 10. As

can be seen, the inlet 615 is provided as a plurality of discrete inlet holes 620. This is advantageous over the use of a groove for the main inlet 615 because a groove as an air bearing has a capacity (because of thecompressable nature of gas) such that vibrations can be set up in such a system. Small diameter inlet holes 620 have a lower volume of gas in them and therefore suffer less from problems arising from capacity.

The use of a further inlet 617 in the form of a groove 633 can be used to ensure a continuous gas flow around the whole circumference of the seal member 12 which would not necessarily be possible when only using discrete inlet holes 620. The provision of the outlets 645 as discrete entities is not a problem because of the provision of the groove 640 which is effective, like chambers 647 and 622, to even out the flow.

The inlets for liquid are not illustrated in the seal member 12 of Figures 10 and 11. The liquid may be provided in the same manner as illustrated in the foregoing embodiments or, alternatively, any of the liquid inlets and outlets as described in European Patent Application Nos. 03256820.6 and 03256809.9.

Embodiment 7

The seventh embodiment is similar to the sixth embodiment except as described below. Figure 12 is a plan view of the underside of the seal member 12 similar to that shown in Figure 11. In Figure 12 the seal member is not provided with a further inlet as in the sixth embodiment though this can optionally be added.

The seal member 12 of the seventh embodiment comprises a gas bearing 715 formed by inlet holes 720 and which is of the same overall design as the sixth embodiment. The inlet 714 comprises a annular groove 740 with only two passages 745, 747 which lead to a gas source and a vacuum source respectively. In this way a high speed flow of gas from the gas source connected to passage 745 towards the vacuum source connected to passage 747 can be established. With thishigh speed flow of gas, immersion liquid can be drained more effectively. Furthermore, by creating a larger restricted vacuum flow in the vacuum chamber, flow fluctuations due to variations in the height of the seal member 12 above the substrate W or other leakage sources in the surface will not influence the vacuum chamber pressure providing the preload for the gas bearing.

Embodiment 8

The eighth embodiment will be described in relation to Figure 14 and is the same as the first embodiment except as described below.

As can be seen from Figure 14, the eighth embodiment has a seal member 12 with an inlet 815 and an outlet 814 just like the first embodiment. However, a further inlet 817 is provided which is arranged so that a jet of gas can be formed which increases the velocity of the gas on the surface of the substrate W below or marginallyradially outwardly of the outlet 14 so that immersion liquid is more effectively removed from the surface of the substrate W. The further inlet 817 has an exit provided by anozzle which is directed towards the substrate W at an angle radially inwardly towards the projection system PL. Thus, the otherwise laminar air flow (with a Reynolds number of around 300) between the inlet 815 and the outlet 814 and which has a simple parabolic speed distribution with a zero speed on the surface of the substrate, which cannot remove the last few micro meters of liquid film from the wafer, is improved because the further inlet 817 ensures that gas with a higher air velocity is in contact with the substrate surface.

From Figure 14 it can be seen that the exit nozzle of the further inlet 817 is provided radially outwardly of the outlet 814 but closer to the outlet 814 than to the inlet 815.

Embodiment 9

The ninth embodiment is illustrated in Figures 15 and 16 and is the same as the first embodiment except as described below.

In the ninth embodiment the mouth of the outlet 914 in the bottom surface of the seal member12 which faces the substrate W, is modified to increase the velocity of air into the outlet 914. This is achieved by reducing the size of the mouth of the inlet 914 whilst keeping the passageway of the outlet 914 the same size. This is achieved by providing a

smaller mouth by extending material of the seal member 12 towards the center of the passage to form an outer addition member 940 and an inner additional member 950. The outer additional member 940 is smaller than the inner additional member 950 and the gap between those two members 940, 950 is approximately 20 times smaller than the remainder of the outlet 914. The mouth is approximately 100 to 300 μm in width.

In Figure 16 a further alternative version of the ninth embodiment is depicted in which a further inlet 917 similar to the further inlet 817 of the eight embodiment is provided. However, in this case the further inlet 917 provides a jet of flow substantially parallel to the surface of the substrate W so that the gas entering the mouth of the outlet 914 is accelerated.

Embodiment 10

The tenth embodiment is illustrated in Figure 17 and is the same as the first embodiment except as described below.

In the tenth embodiment the efficiency of liquid removal is improved by increasing the velocity of gas on the surface of the substrate W along the same principles as in the eight embodiment. Gas leaving inlets 1015 and movingradially inwardly towards an outlet 1014 passes underneath an annular groove 1018. The effect of the groove, as illustrated, is for the gas to enter the groove on its radially outer most side and to exit it, with an angle towards the substrate W, on the radially inward side. Thus, the speed of the gas on the surface of the substrate W at the entrance to the outlet 1014 is increased and liquid removal efficiency is improved.

It will be clear that features of any embodiment can be used in conjunction with some or all features of any other embodiment.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.

CLAIMS:

1. A lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate; and
- a liquid supply system for at least partly filling a space between the final element of said projection system and said substrate with a liquid, characterized in that said liquid supply system comprises:
- a seal member extending along at least a part of the boundary of said space between the final element of said projection system and said substrate table; and
- a gas seal means for forming a gas seal between said seal member and the surface of said substrate.

2. Apparatus according to claim 1, wherein said gas seal means is a gas bearing for supporting said seal member over said substrate.

3. Apparatus according to claim 1 or 2, wherein said gas seal means comprises a gas inlet and a first gas outlet formed in a face of said seal member that opposes said substrate, means for supplying gas under pressure to said gas inlet and vacuum means for extracting gas from said first gas outlet.

4. Apparatus according to claim 3, further comprising a further inlet connected to a gas source and positioned between said first gas outlet and said gas inlet.

5. Apparatus according to claim 4, wherein said further inlet comprises a continuous annular groove in a surface of said seal member facing said substrate.

6. Apparatus according to claim 5, wherein a radially innermost corner of said groove

has a radius.

7. Apparatus according to any one of claims 3 to 6, wherein said first gas outlet comprises a continuous annular groove in a surface of said seal member facing said substrate.

8. Apparatus according to any one of claims 3 to 7, wherein said first gas outlet and/or said gas inlet comprise chambers between said means for supplying and said vacuum means respectively and an opening of said inlet or outlet in said surface which chamber provides a lower flow restriction than said opening.

9. Apparatus according to any one of claims 3 to 8, wherein said gas inlet comprises a series of discrete openings in a surface of said seal member facing said substrate.

10. Apparatus according to any one of claims 3 to 9, wherein a porous member is disposed over said gas inlet for evenly distributing gas flow over the area of said gas inlet.

11. Apparatus according to any one of claims 3 to 10, wherein said seal member further comprises a second gas outlet formed in said face of said seal member that opposes said substrate, said first and second gas outlets being formed on opposite sides of said gas inlet.

12. Apparatus according to any one of claims 3 to 11, further comprising means for varying the level of a portion of said face between said first gas outlet and said gas inlet relative to the remainder of said face.

13. Apparatus according to any one of claims 3 to 12, further comprising means for varying the level of a portion of said face between said first gas outlet and an edge of said face nearest said optical axis relative to the remainder of said face.

14. Apparatus according to any one of claims 3 to 13, wherein said gas seal means comprises a channel formed in said face and located nearer to the optical axis of the projection system than said first gas outlet.

15. Apparatus according to claim 14, wherein said channel is a second gas inlet.

16. Apparatus according to claim 15, wherein said channel is open to the environment above the level of liquid in said space.

17. Apparatus according to any one of claims 3 to 16, wherein said gas inlet is located further outward from the optical axis of said projection system than is said first gas outlet.

18. Apparatus according to any one of claims 3 to 17, wherein said gas in- and out-lets each comprise a groove in said face of said seal member opposing said substrate and a plurality of conduits leading into said groove at spaced locations.

19. Apparatus according to any one of claims 1 to 18, further comprising sensors for measuring the distance between said face of said seal member and said substrate and/or the topography of said substrate.

20. Apparatus according to any of claims 1 to 19, further comprising control means to control the gas pressure in said gas seal means to control the stiffness between said seal member and said substrate and/or the distance between said seal member and said substrate.

21. Apparatus according to any one of the preceding claims, wherein the gap between said seal member and the surface of said substrate inwardly of said gas seal means is small so that capillary action draws liquid into the gap and/or to prevent gas from said gas seal means entering said space between said projection system and said substrate.

22. Apparatus according to any one of the preceding claims, wherein said seal member forms a closed loop around said space between said projection system and said substrate.

23. A lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;

- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate; and
- a liquid supply system for at least partly filling a space between the final element of said projection system and said substrate with a liquid, characterized in that

said space is in liquid connection with a liquid reservoir through a duct, and the minimum cross sectional area of said duct in a plane perpendicular to the direction of fluid flow is at least $\pi\left(\frac{8\Delta V\eta L}{\pi\Delta P_{max}t_{min}}\right)^{1/2}$ where ΔV is the volume of liquid which has to be removed from said space within time t_{min}, L is the length of the duct, η is viscosity of liquid in said space and ΔP_{max} is the maximum allowable pressure on said final element.

24. The apparatus of claim 23, wherein said space is enclosed such that when liquid is present in said space, said liquid has no free upper surface.

25. A lithographic projection apparatus comprising:
- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate; and
- a liquid supply system for at least partly filling a space between the final element of said projection system and said substrate with a liquid,

characterized in that said liquid supply system further comprises on a top surface of liquid in said liquid supply system, suppression means for suppressing development of waves and including pressure release means.

26. Apparatus according to claim 25, wherein said suppression means comprises a flexible membrane.

27. Apparatus according to claim 25 or 26, wherein said suppression means comprises a mesh such that the maximum area of said top surface of said liquid is equal to the mesh

opening.

28. Apparatus according to claim 25, 26 or 27, wherein said suppression means includes a safety valve for allowing the passage of liquid above a certain pressure therethrough.

29. Apparatus according to claim 25, wherein said suppression means is a high viscosity liquid which is immiscible with said liquid.

1. ABSTRACT

Lithographic Apparatus and Device Manufacturing Method

In a lithographic projection apparatus a seal member surrounds a space between the final element of a projection system and a substrate table of the lithographic projection apparatus. A gas seal is formed between said seal member and the surface of said substrate to contain liquid in the space.

2 Representative Drawing

Fig. 2

Fig. 1

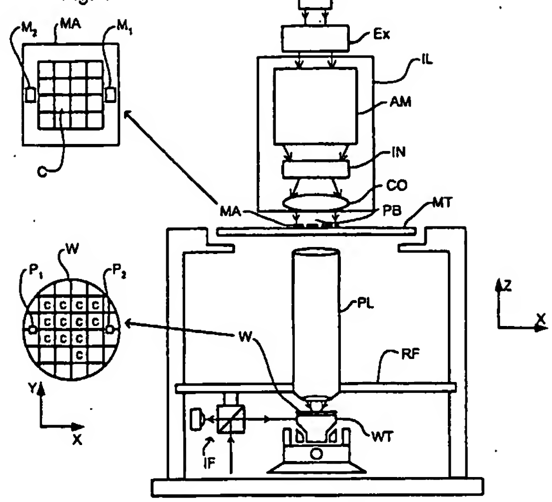


Fig. 2

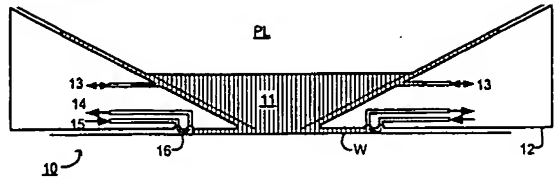


Fig. 3

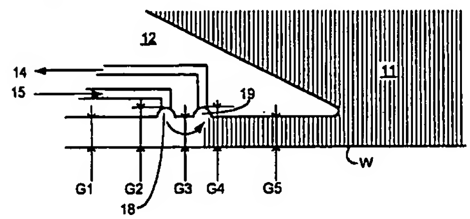


Fig. 4

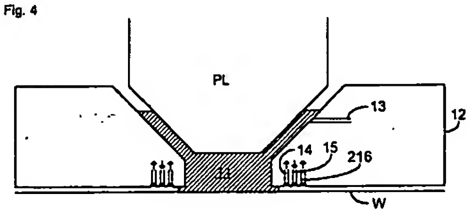


Fig. 5

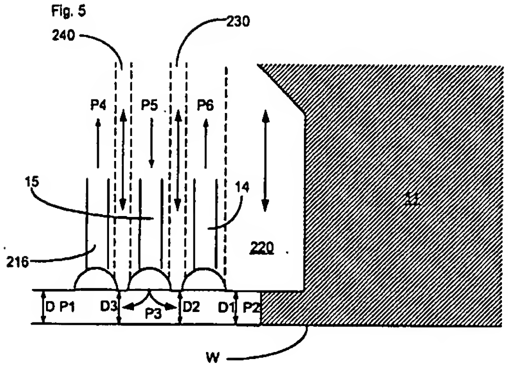


Fig. 6

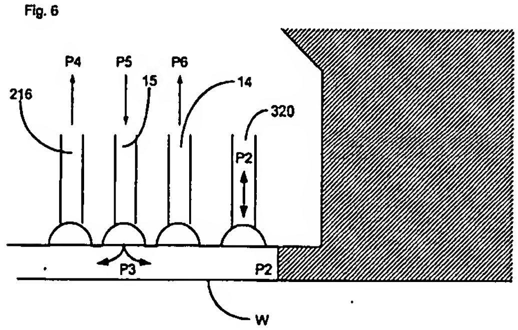


Fig. 7

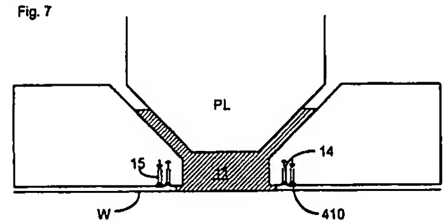


Fig. 8

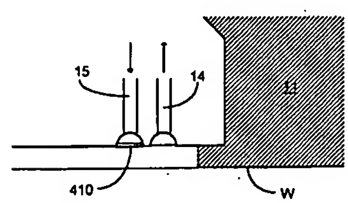
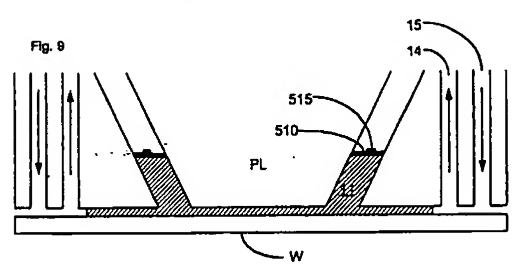


Fig. 9



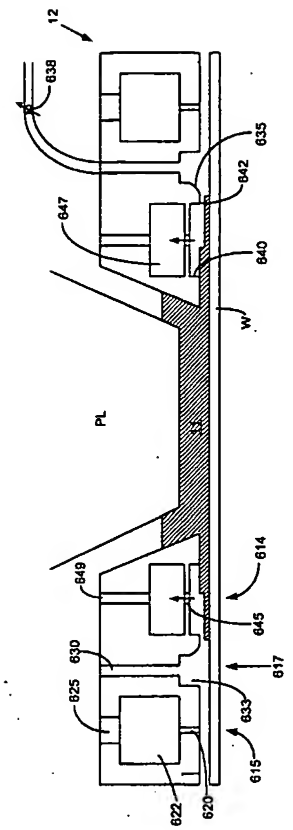


Fig. 10

Fig. 11

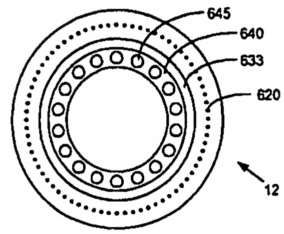


Fig. 12

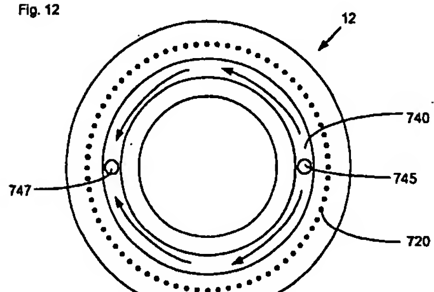


Fig. 13

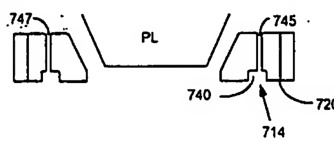


Fig. 14

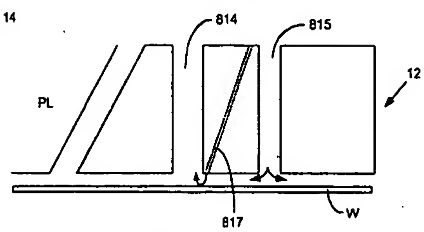


Fig. 15

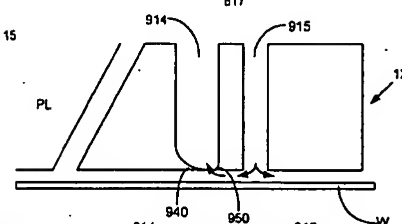


Fig. 16

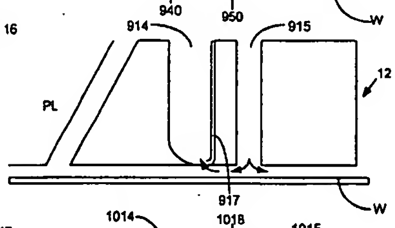


Fig. 17